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THE DESIGN AND DEVELOPMENT OF THE RESIDUAL HEAT REMOVAL SYSTEM, SUSQUEHANNA STEAM ELECTRIC STATION, UNITS 1 AND 2

The Pennsylvania Power and Light Company, anticipating increased needs for electric power, decided that a nuclear plant would be economically advantageous to their system. From among the five or six major companies then involved in building large nuclear plants, PP&L, in 1970, selected Bechtel Corporation as the architect-engineer for their Susquehanna Steam Electric Station (Nuclear Power Plant).

This case history, written in 1973, details Bechtel's work in preliminary planning, site selection, alternative heat removal plans, safety requirements, and, to some degree, sets forth specifications required by the Atomic Energy Commission for construction of a nuclear power plant.

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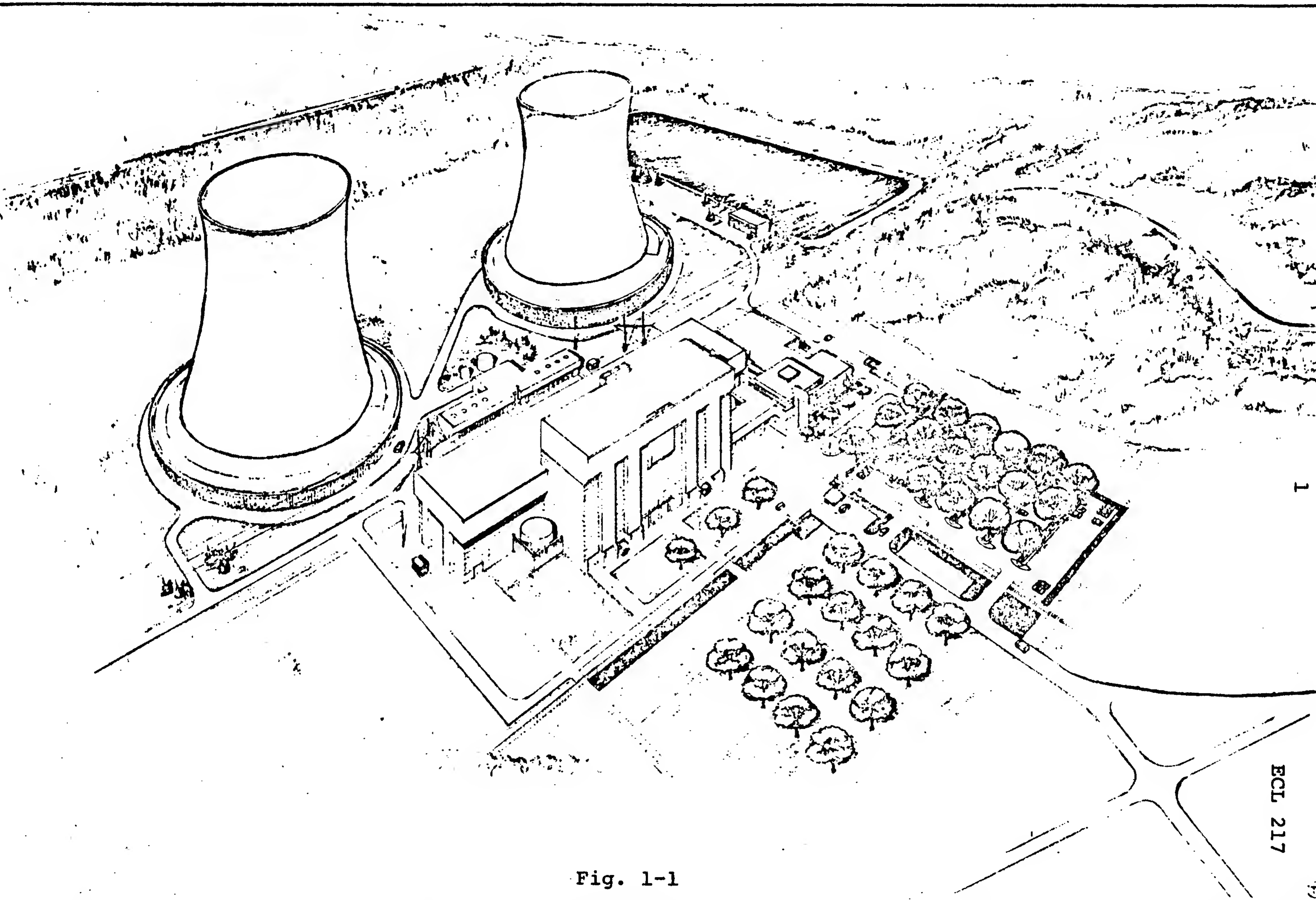

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Fig. 1-1

PENNSYLVANIA POWER & LIGHT COMPANY — SUSQUEHANNA STEAM ELECTRIC STATION UNIT 1 & UNIT 2
BIRDSEYE VIEW LOOKING NORTHWESTWARD

BECHTEL CORPORATION
SAN FRANCISCO
JOB NO 8856 DEC '71

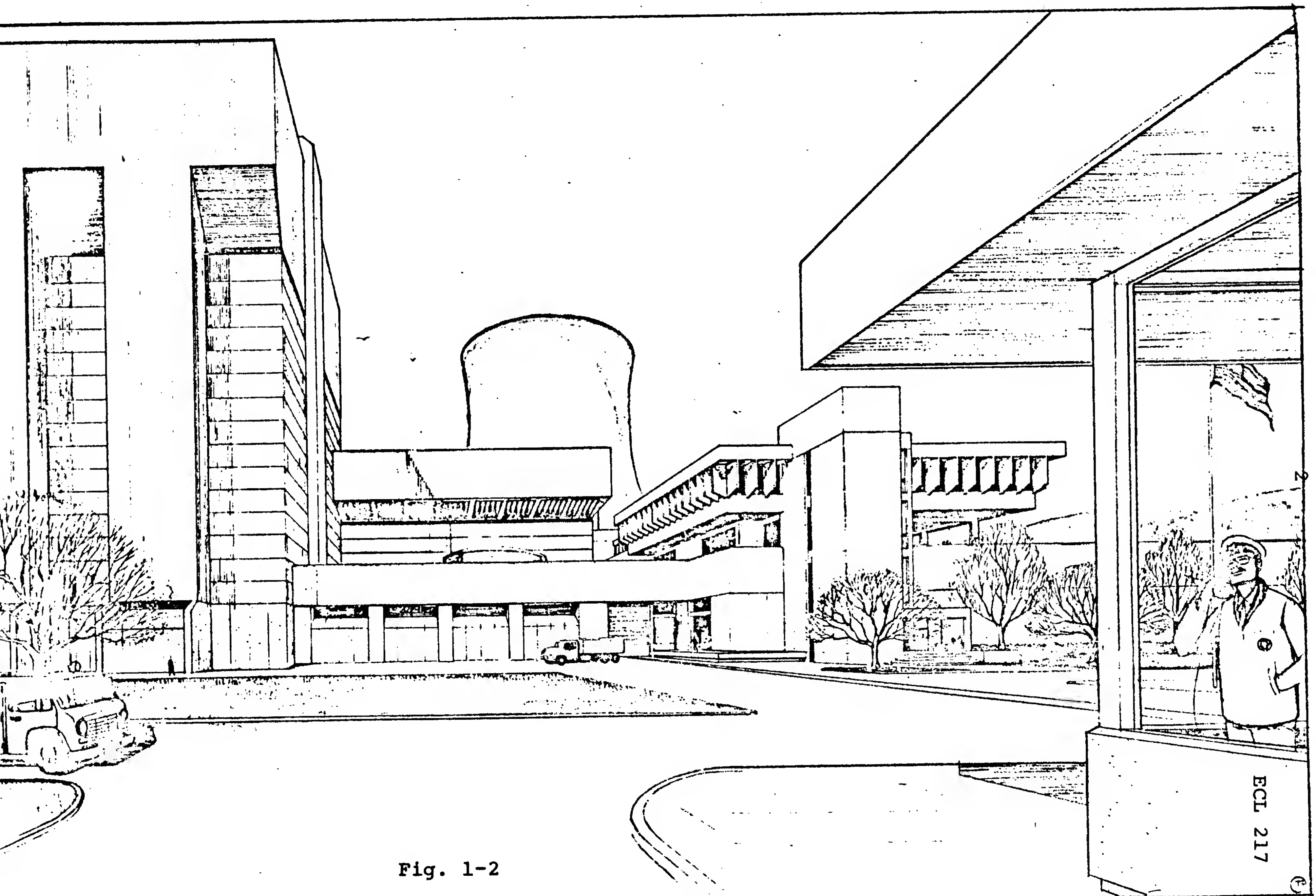

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Fig. 1-2

NNSYLVANIA POWER & LIGHT COMPANY

SUSQUEHANNA STEAM ELECTRIC STATION UNIT 1 & UNIT 2
VIEW FROM MAIN ENTRANCE LOOKING WEST

BECHTEL CORPORATION
SAN FRANCISCO
JOB NO 8856 DEC '71
SK-A-36

1. INTRODUCTION

1.1 Background

Anticipating the future need for electric power, the system planning group of the Pennsylvania Power and Light Company (PP&L) decided that 1100 Megawatts of capacity should be added to their system in the year 1975 and again in 1977. After an economic study was made to determine the kind of plant (fossil plant, hydro plant, nuclear plant), it became apparent that a nuclear plant had an economic advantage to their system.

The Susquehanna Steam and Electric Station is financed by and being built for the Pennsylvania Power and Light Company to meet this power demand. Artist impressions of the plant are shown in Figures 1-1 and 1-2, pp. 1 and 2. Basically, the plant consists of two electric generating units, each utilizing a boiling water nuclear reactor as a heat source, and a turbine generator for electricity production. Each of the units has its own natural draft tower for dissipation of heat from the condensers. PP&L made commitments for the "1967 product line" General Electric (G.E.) Boiling Water Reactor to the G. E. Atomic Power Equipment Department in San Jose in 1968. At the same time they made commitments for turbine generators to the G.E. Large Steam Turbine Department in New York.

1.2 Selection of an Architect-Engineer

There are five or six major companies involved in building large nuclear power plants. To select one of them, a client normally asks for some indication of interest on the part of these various firms. The client may ask for qualifications, experience, manpower, financial resources; and/or the client may visit and directly interview the firms. If the client is interested, he will ask for a proposal. The proposal would include the fee structure, the approximate schedule, and if the client asks for it, as PP&L did in this case, to name the probable key personnel in the project team. In this way, the client may compare one company with another.

In the power industry today, the licensing requirements and labor costs are changing so rapidly that it is difficult to establish how much a plant will cost. In the nuclear industry a job can run for over ten years. The work is usually done on a reimbursable basis.

In August 1970, Bechtel was selected as the Engineer-Contractor to design and construct the facility for PP&L. Originally, the design work was to be done in Bechtel's Gaithersburg, Maryland office, but after a few weeks, PP&L decided the work should be done in the San Francisco office. The San Francisco

office then was doing two similar jobs, and G. E., with whom PP & L had contracted for the reactor was located in San Jose.

1.3 The Bechtel Corporation

Bechtel is a large consulting and construction engineering corporation. Its San Francisco power division, which has about 7000 employees, is responsible for the design and construction of power plants. Within the division there are construction, engineering, service and business development departments. A project team for a large two unit nuclear plant usually consists of about 150 to 200 people, depending on the project. The project engineer is responsible for the design of the facility and for signing all the specifications for the job. No change can be made in the field without his prior approval. An organization chart for the Susquehanna project team is shown in Fig. 1-3, p. 5. Mr. Sanford Heisler was named Project Engineer to the Susquehanna Steam Electric Station. As Project Engineer, he was responsible for the work done.

Mr. Heisler graduated from the University of California in 1948 with a B. S. degree in Mechanical Engineering. Additional post-graduate studies included Nuclear Power, Engineering Management, Industrial Management and Engineering and Construction Planning. From 1948 to 1951 he was employed by the Chevrolet Division of General Motors, Oakland, as an Engineer. He was employed by Bechtel Corporation in 1951 in the Power and Industrial Division. He was recalled to active duty in the U. S. Navy during the Korean War, 1952-1954. After returning to Bechtel, Mr. Heisler worked on a variety of projects, including assignment as a mechanical engineer for the design of the Big Rock Nuclear Power plant and Mechanical Engineering Group Supervisor for the design of the Tarapur Nuclear Power Station. Later assignments included Mechanical Engineering Group Supervisor for the design of the NASA, MSC Houston Space Chambers and assignment as Assistant to the Division Manager of Engineering, P & I Division. In 1968, he became Project Engineer on the Taiwan Power Company Nuclear Plant in Taiwan. In 1970, he was assigned to be Project Engineer to the Susquehanna Steam Electric Station and in January, 1973, he was assigned as Assistant Project Manager on this same project. He is a member of the American Society of Mechanical Engineers, American Nuclear Society and a registered Professional Engineer in the Commonwealth of Pennsylvania and the State of California.

1.4 Bechtel and PP&L Relationship

Since the Susquehanna Steam Electric Station (SSES) is financed by PP&L, final design decisions are made by them. Bechtel only makes recommendations to PP&L. Bechtel's responsibility to the client is to give the client the best advice

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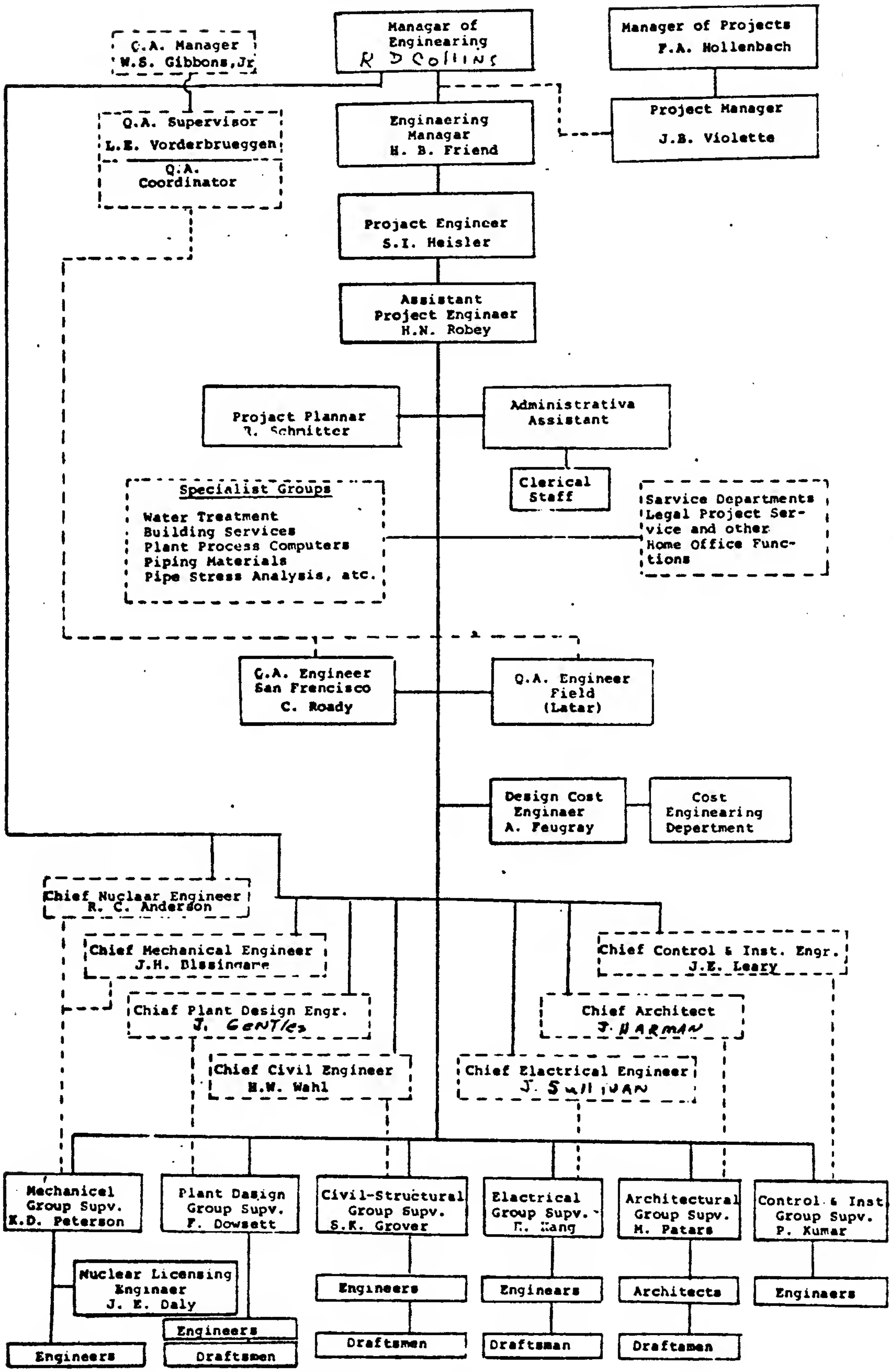
BECHTEL CORPORATION - JOB NO. 8856
ENGINEERING
PROJECT ORGANIZATION

PENNSYLVANIA POWER & LIGHT COMPANY
SUSQUEHANNA STEAM ELECTRIC
STATION, UNITS 1 AND 2



Note: Dashed lines indicate technical responsibility.

Fig. 1-3

2/15/

on which to make decisions. However, the decision of the client is final. In the case of Susquehanna, Bechtel suggested four major changes which PP&L approved: (1) plant location - originally the site was located in the flood plain. Bechtel recommended it be moved to a higher elevation, (2) reactor containment - change from a Torus Drywell to an Over-under type, (3) turbine layout - change plant layout arrangement from peninsula to "in line", (4) Railroad - to build a rail spur to the plant.

2. THE PRELIMINARY SAFETY ANALYSIS REPORT (PSAR)

2.1 Preliminary Work

Bechtel received a letter of authorization on 12 August 1970 from PP&L to begin the design and construction of the Susquehanna Plant. The four senior people whom Bechtel selected for this project went to a meeting with PP&L on 18 August 1970, in Allentown, Pennsylvania, which was headquarters for PP&L. This was the starting point at which Bechtel actually began to work on the project.

Since the Susquehanna Steam Electric Station (SSES) is a nuclear facility, Bechtel was immediately faced with the problem of obtaining the necessary government approvals for the field work. In the sense that the SSES is PP&L's plant, PP&L must apply to the Atomic Energy Commission (AEC) for a construction permit, then, later, after the plant is built, they must apply for operating licenses.

The major step in the application of a construction permit is the filing of the Preliminary Safety Analysis Report (P.S.A.R.) This report effectively covers all the portions of the plant and the site, with particular emphasis on anything related to the safety and health of the public. When the AEC receives these documents, they study them and address certain specific questions to the applicant. These questions, when developed, cause a series of meetings to take place between the AEC staff, and the applicant and its consultants to answer the AEC's questions. These responses are then formalized to become a part of the P.S.A.R. This up-dated P.S.A.R. is the commitment of the utility to the AEC and the public.

After Bechtel was given the job, P.S.A.R. work was begun immediately. Mr. John Daly, the Nuclear-Licensing Engineer in charge, and the Mechanical/Nuclear engineering group were responsible for this work. One of the first decisions made was to computerize the P.S.A.R. so that any changes in the original copy could be

made easily. Bechtel coordinated input with G. E. and several consultants that PP&L had hired, and started putting the P.S.A.R. together.

2.2 The Site

In the P.S.A.R., a series of studies on population, land use, geology, hydrology, seismology, and meteorology was conducted to establish a basis for selection of design standards for the plant.

The site is located in Salem Township, Luzerne County, Pennsylvania, on the west bank of the Susquehanna River. The site for Susquehanna Steam Electric Station is shown in Fig. 2-1, p. 8. It is four miles south of Shickshinny and five miles northeast of Berwirk. It is approximately 1522 acres in area and is owned by the Pennsylvania Power and Light Company. The nearest population center is Hazelton, Pennsylvania, which is 12 miles northeast of the site. The population within 10 miles of the proposed site is sparse. The minimum exclusion distance is 1800 feet, and there are no private residences located inside the exclusion area. Public recreation areas will be provided by PP&L in those areas of the site outside the exclusion boundary. A low population zone with a radius of 3 miles surrounds the site, where there are no schools, hospitals, nursing homes, mental institutions, prisons, or military bases.

If the people in the nearby communities wish to protest, they can intervene at the licensing hearings, which are public and open. Some plants have had very active intervention and have been delayed for several years. In Susquehanna Station, PP&L has had no intervention to date (Spring 1973). The utility will spend roughly 15 million man hours - about 200 million dollars - for construction work in the field. A pay roll of this size can stimulate the local economy. After construction work, the plant will have a regular staff of 80 to 90 people, and the plant will be a purchaser of goods and services in the local area. In general, it will improve the economy of that area.

2.3 Relocation of the Plant

About five miles north of the site, in the vicinity of Shickshinny, the Susquehanna River changes direction from a south-west course to almost due south. About two miles south of the site, near Beach Haven, the river once again resumes its southwestward course (Fig. 2-2), p. 9. The Susquehanna River is about 700 feet wide and 480 feet above sea level near the site. The initial location for the plant was beside the river at 510 foot elevation. Then a few weeks later, it was found that for the design flood level in that area, the plant would be under water.

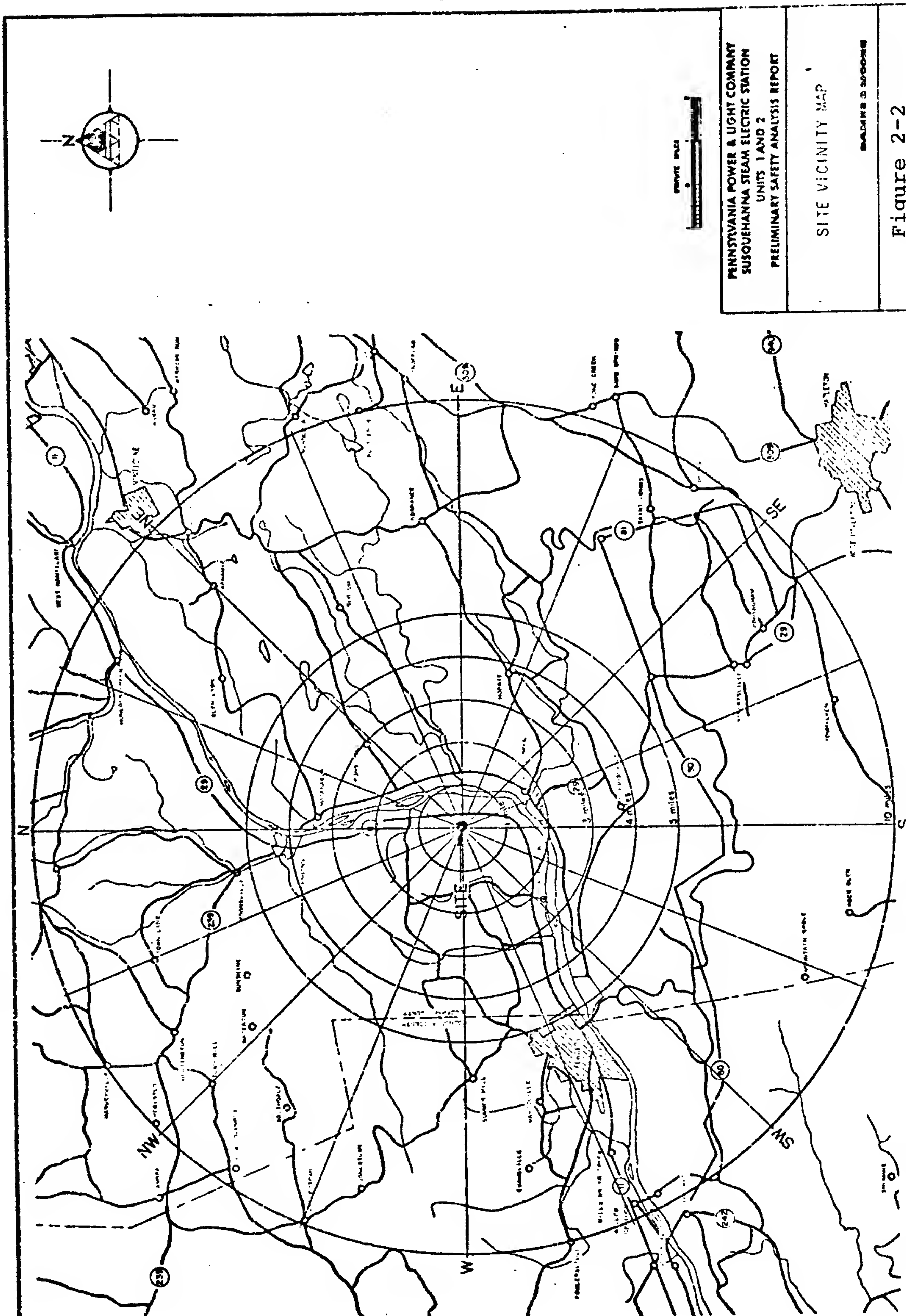

PENNSYLVANIA POWER & LIGHT COMPANY
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 AND 2
PRELIMINARY SAFETY ANALYSIS REPORT
SITE VICINITY MAP
N
E
S
W
NW
SE
SW
SITE
3 miles
4 miles
5 miles
10 miles
11
29
81
90
239
242

Figure 2-2

On September 21, 1970, Mr. Heisler went to Allentown for a meeting with PP&L to discuss the relocation of the plant to a higher elevation (see Exhibit 2-1, pp. 11-13), where the land was also owned by PP&L. The new location is about 150 feet above the flood plain adjacent to the river. This is the first leveled spot and a natural location for the plant. In the flood near Wilkes-Barre in the winter of 1972, the original site on the plain was 15 feet under water, which validated the decision to move the plant.

2.4 Cooling Towers

As part of the cooling system, hyperbolic natural draft towers about 500 feet high, are used as the heat sink. The cooling towers are connected closed loop to the condensers so that hot water from the condensers is cooled by evaporation in the tower. When the two generating units are operating at maximum capacity, an average of about 50 cfs. (a peak of 62 cfs) is required from the water supply to replace the water lost by evaporation. A bleed stream from the river will provide this make-up water. In the process of evaporation, the impurities that are dissolved do not evaporate with the water. A sample of impurities is in Table 2-1, p. 14. If the concentration of those impurities is not kept down to a certain limit, there is a chance that they might degrade the distribution system, the piping, valves, and any of the delicate instruments in the system. In addition, since the circulating water will be chlorinated, the chlorides in the water might attack the concrete of which the cooling tower basin is constructed.

In order to maintain a low chemical concentration in the water, a continuous bleed is provided to bleed off the water with the high concentration while fresh water with low chemical concentration is added. The bleed-off is called the blowdown.

2.5 Retention Pond

Because of environmental concern, a pond is to be installed which will be adequate to retain one day's worth of blowdown from the cooling tower, so that if there are any "off-standard" conditions the water may be treated before it is released off-site. Twenty-four hour retention would amount to about 15 million gallons of blowdown water.

2.6 The Residual Heat Removal System (RHRS)

In the event of a reactor shutdown or "scram", control rods made of neutron absorbing materials (Boron, Cadmium, Hafnium) are inserted between the fuel elements to stop the chain reaction immediately. In the fission process there are a family of subordinate residual products with variable half lives that generate additional heat. This "residual heat"

BECHTEL

COPY

0261

September 30, 1970

Pennsylvania Power & Light Co.
901 Hamilton Street,
Allentown, Pennsylvania 18101

Attention: Mr. John F. West, Jr.

Subject: Pennsylvania Power & Light
Susquehanna Steam Electric
Station Units 1 and 2
Job 8856
Plant Foundation Study
BLP-3

Dear John:

In our meeting with you in Allentown on September 21, 1970, it was decided to relocate the plant from the low lying site to an upland site above elevation 550 feet.

Prior to this decision and before the éffects of the probable maximum flood were fully evaluated, we had been conducting plant location studies for the low lying site by the river at the unimproved grade of 510' with an estimated final plant grade of 522'.

While the decision to move to the higher ground supersedes the results of this study we are forwarding the study results to you to allow you to complete your files.

As you will recall, the depth to rock below grade varied markedly on the site and hence the purpose of this study was to obtain rough Order of Magnitude cost differentials for the subsurface work for the units for three alternate locations. In all cases the foundations of the Class I structures and the Turbine Building pedestal were considered to be founded either on bedrock or on suitable subsurface material such as lean concrete or engineered fill. Class II structures were assumed to be unaffected by location and do not represent differential costs for purposes of this brief study. The additional land requirements for the 1/2 mile exclusion zone radius were also assessed.

Mr. John F. West, Jr.
September 30, 1970
Page 2

Enclosed is our drawing SK-C-6 Revision A "Plant Location Study" showing, the three locations A, B and C considered and the Plant Section with bed rock elevations (obtained from bedrock contour map LC-73555-0). Locations A and B' are near the center of the site while C is about 3000 feet to the south of the center of the site.

Brief conclusions of this study are:

1) The use of pile foundations were considered unsuitable due to the presence of large boulders (5ft. to 20ft.) in the overburden. It was felt that these boulders would prevent the proper driving of the piling. Caisson foundations presented a major dewatering problem, boulder interference problems similar to the piling problem above and a potential construction schedule delay.

2) Considering Case A as the base case and using lean concrete as the subsurface material to transfer foundation loads to bedrock, the savings for Case B and Case C over Case A were $700,000 and $6,500,000 respectively.

3) Using engineered fill as foundation material, the savings for Case B and Case C over Case A were $700,000 and $4,000,000 respectively. There is however a question as to the availability of the required amount of the proper quality fill material.

4) The following additional areas in the study were also identified, however their impact on the cost of the plant was not estimated for this study since they would not in our opinion, be sufficient to have a major effect on our findings.

    a) Additional plant facilities costs resulting from the different locations.

    b) Licensing requirements.

    c) Units #3 and #4 considerations.

    d) Schedule effect due to greater volumes of fill etc.

    e) Backfill from elevation 510 to elevation 522 (common to all cases).

Mr. John F. West, Jr.
September 30, 1970
Page 3

f) Cost of additional land purchase for exclusion zone requirements. For location B and C, 10 and 128 acres of additional land are required, respectively. The cost for these would somewhat offset the savings above.

In conclusion, location C is more favorable and would have been recommended.

Very truly yours,

S. I. Heisler,
Project Engineer

SKG:mt
Encls.

Exhibit 2-1

SSES

TABLE 2-1

CHEMICAL ANALYSES OF THE NORTH BRANCH

SUSQUEHANNA RIVER AT THE SITE

APRIL 1968 THROUGH AUGUST 1970 *

	Minimum	Maximum	Average
Silica (SiO_2)	0.09	5.1	3.4
Iron (Fe)	0.02	1.72	0.40
Aluminum (Al)	0.00	0.56	0.10
Manganese (Mn)	0.00	0.95	0.11
Calcium (Ca)	12.6	65.2	32.9
Magnesium (Mg)	3.4	21.8	9.6
Sodium (Na) & Potassium (as Na)	0.00	9.4	2.7
Bicarbonate (HCO_3)	25.6	81.8	55.2
Sulfate (SO_4)	12.8	155	60.0
Chloride (Cl)	3.6	18.2	10.8
Nitrate (NO_3)	0.5	4.0	1.7
Phosphate**	0.00	0.4	0.21
Dissolved Solids	79.6	388.8	206.8
Hardness as $CaCo_3$	51.5	248.0	125.0
Dissolved Oxygen	7.8	14.2	10.6
Biochemical Oxygen Demand (5 day BOD)	0.8	6.6	2.9
Temperature F.	34	85	63
pH	6.5	7.4	-
Color	5.5	111.0	38.8

All values in parts per million, except those for temperature, pH and color.

* PP&L Records

** Based on only three samples

decays exponentially, so that in a few seconds after scram, the energy will be down to 6%. For an eleven hundred Megawatt plant, six percent capacity is still a lot of heat. The system of heat exchangers, pumps and associated piping that remove this heat is the Residual Heat Removal Service Water (RHRSW) system.

2.7 P.S.A.R. Filed

The P.S.A.R. was filed with the application of the construction permit on April 1, 1971. It consisted of 6 volumes (2 inches thick each) and was shipped to Washington for the AEC to review. The filing of the P.S.A.R. was the first milestone in the project.

2.8 AEC Class I and Class II Specifications

In any discussion of nuclear power plant design, two terms inevitably come up which require further explanation, These are Class I and Class II systems.

Certain station structures must remain functional and/or must protect vital equipment or systems, both during or after emergency disaster conditions. These disasters can include both natural catastrophes such as hurricanes, tornadoes, earthquakes, etc., or man-made catastrophes such as train wrecks, etc. In either case, the most severe condition that could be encountered must be used as the design criteria. In order to establish design loadings and loading combinations, buildings, structural systems, certain functional systems and equipment are separated into either Class I or Class II specifications.

Class I structures are those whose failure could cause or increase the severity of any postulated accident, cause release of excessive radioactivity, or those essential for safe shutdown and immediate or long term operation following an accident.

Class II structures are those whose failure would not result in the release of significant radioactivity and would not prevent reactor shutdown. The failure of Class II structures, systems, and equipment may interrupt power generation.

A structure or equipment designated Class II cannot degrade the integrity of any structure or equipment designated as Class I. Although a structure may be Class I, less essential portions may be considered Class II, if they are not associated with loss of function, and their failure does not render the Class I portion inoperable. The AEC specifically states that the Class I systems will perform one of two functions: (1) it will prevent the release of radioactive material, or, (2) it will mitigate the consequences of such release.

In designing to Class I requirements, the system or equipment must be failure proof for all of the maximum catastrophes mentioned previously. This type of design specification results in considerable redundancy in terms of backup systems for backup systems, and two or three valves where one would be used in a Class II specification. It also results in the use of components and systems that are subject to the highest qaulity controls through inspections, extensive use of various non-destructive testing techniques, and rigid adherence to the codes or standards designated by the AEC.

The extensive testing and inspection of Class I systems results in considerable extra expense. For this reason, another important consideration is brought out in terms of relative economies involved in selecting Class I systems. This consideration involves the use of either active or passive systems. An active system involves some mechanical or electrical device to make it function, such as a mechanical draft cooling tower. A passive system functions by virtue of its being there, such as the natural draft cooling tower or a cooling pond. In general, a passive system for heat dissipation is more expensive, easier to license and maintain the same level reliability over the long run, and requires less maintenance and upkeep.

3. ENGINEERED SAFEGUARDS SERVICE WATER SYSTEM

3.1 Introduction

With the filing of the PSAR in April, 1971, the real problems of specifically describing and designing the Susquehanna project fell into Mr. Heisler's lap. As project engineer, he was in responsible charge of all the various engineering branches, i.e., mechanical, civil, electrical, to design a workable plant that would (1) satisfy the guidelines set forth by the PSAR, (2) satisfy the specifications set by the client (PP&L), and (3) satisfy the licensability criteria set forth by the Atomic Energy Commission (AEC).

One of the questions left to be answered was the problem of designing a system which could reliably and safely transfer heat generated by decaying fission products in the event of some emergency shutdown of the facilities. Mr. Heisler had as his mechanical design leader, Mr. Kenneth Peterson. Between Mr. Peterson, Mr. Heisler and other project leaders with similar experience, a series of seven alternatives including the once-through river base scheme, submitted originally in the PSAR, were considered in the Engineered Safeguards Service Water System (E.S.S.W.).

The E.S.S.W. pertains specifically to two interconnected systems. The first is the "Residual Heat Removal Service Water System (RHRSW) and the second is the "Emergency Service Water System (ESW). The RHRSW has already been briefly described in section 2.6. The ESW is an emergency equipment cooling water system required to cool certain equipment during normal and emergency shutdown of the plant.

Around the middle of 1971, Mr. Peterson assigned one of his staff, Mr. Thomas Naghdi, to completely study the alternatives for the purposes of arriving at some optimum situation of an ultimate heat sink with a minimum of cost. The following draws heavily on the final report submitted to PP&L in October of 1971.

3.2 Description of the Alternatives

The general data used in the alternatives discussed in the following sections are tabulated in Table 3-1, p. 18, "Engineered Safeguards Service Water Study Matrix". Equipment has been selected on the basis of suitability, past performance, and acceptability to the AEC, as well as cost and maintenance considerations. The use of unproven equipment, i.e., larger than ordinary sizes, or particular types, is greatly discouraged since it opens the question of reliability and it is probable that the AEC would require a full scale test to prove such equipment before any licensing could be considered.

In Alternative I, (Base Scheme), the Susquehanna River is used as the source, or ultimate heat sink, of Engineering Safeguards Service Water (ESSW). The ESSW pumps and screen wash pumps are housed in a combined Class I pump structure located approximately 3,000 feet west of the Susquehanna River, about 300 feet west of U. S. Highway 11 as shown diagrammatically in Fig. 3-1, p. 19. The pump structure is located so as to meet the maximum flood criterion and at the same time provide accessibility to the pump structure in the event of the postulated maximum flood level.

The ESSW supply lines are routed from the pump structure to the main building in two physically separate trenches as shown in Fig. 3-1. After supplying cooling water to the respective heat transfer apparatus, the spent cooling water is returned to the river via the existing retention pond.

Fig. 3-1a, p. 20, shows Alternate I with an infiltration type intake such as used at the Montour plant of PP&L. For purposes of this study the Montour type intake was evaluated with all alternatives at the request of PP&L. The preliminary design consists of two 48" perforated reinforced concrete intake pipes with 4 rows of 1" diameter holes, on 24" centers, in the upper half of each pipe for accommodating basket screen inserts. The

ALTERNATES – EMERG WTR SUPPLY SOURCE	1 TYPE OF POND	2 "INTAKE" STRUCT.	3 PUMP STRUCTURE	4 ESW PUMPS	5 RHRSW PUMPS	6 * MAKEUP PUMPS
(A) I SUSQ. RIVER BASE SCHEME – AS SHOWN IN THE PSAR SUB MITTAL APR. 1, 1971	RETENTION POND (CLASS II) SIZE: 10' DEEP MAX. VOL: 65x10³ CU YDS	(CLASS I) FLOW: 60,000 GPM TRASH BARS: 2½"x⅜" – 3" c/c MAX. FLOOD LEVEL: 548' MIN. WTR LEVEL: 484' VEL. THRU BARS: .75 FPS	(CLASS I) SIZE: 51'x58'x25' H OPERATING FL. EL.: 550' BOTTOM OF PIT EL.: 470' TRAV. SCREENS QUANTITY: 2 (SPLASH-PROOF) SIZE: 10' WIDE x ¼" MESH, #12 GA. STAINLESS STEEL FRAME: 4-POST TOTAL LOAD @ 460 V: 15 KW	(CLASS I) CODE: ASME SECT VIII QUANT: 2 FULL-CAP. TYPE: VERT. TURBINE, WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARINGS SETTING: 80' RATING: 8000 GPM @ 350' HEAD & 1800 RPM TOTAL LOAD @ 4KV: 660 KW	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT: 8 ¼-CAP. TYPE: VERT. TURBINE, WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARINGS SETTING: 80' RATING: 4500 GPM @ 400' HEAD & 1800 RPM TOTAL LOAD @ 4KV: 9280 KW	(CLASS II) CODE: ASME SECT VIII QUANT. 3 ⅓-CAP. TYPE: VERT. TURBINE WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARINGS SETTING: 80' RATING: 15,000 GPM @ 320' HEAD & 900 RPM TOTAL LOAD @ 4KV: 3390 KW
** (C) ** III SPRAY POND FOR COOLING W/ RETENTION POND USED FOR EMERG MAKEUP	SPRAY POND (CLASS I) SIZE: 700'x105'x7' DEEP VOL: 25x10³ CU YDS NO. SPRAY NOZZLES: (1408) 1½" STAINLESS STEEL RETENTION POND (CLASS I) VOL: 65x10³ CU YDS	a ESW & RHRSW PPS SUCTION SUMP (I) FLOW: 44,000 GPM NO. SCREEN: 2 (FIXED) SIZE: 6x16'x⅜" MESH ... 55 b MAKEUP PPS TRASH RACK (II) FLOW: 30,000 GPM BARS: 2½"x½" – 3" c/c MIN. WATER LEVEL: 484' VEL. THRU BARS: .75 FPS c EMERG MAKEUP PPS SUCTION SUMP (I) (2) 6'x3'x⅜" MESH SCREENS ... EL. 55	a EMERG PP STRUCTURE (I) SIZE: 50x35x25' H OPERATING FL. EL.: ~ GRADE b MAKEUP PP STRUCT. (II) SIZE: 20'x30x25' H OPERATING FL. EL.: 530' BOTTOM OF PIT EL. 450' MIN. WTR LEVEL EL.: 484' NO. OF TRAV. SCREENS: 2 (SPLASH-PROOF) SIZE: 10' WIDE x ¼" MESH, ... 55 FRAME: 2-POST c EMERG MAKEUP PP STRUCT. (I) SIZE: 10'x15'x10' H OPERATING FLOOR EL.: ~ GRADE	(CLASS I) CODE: ASME SECT VIII QUANT: 2 FULL-CAP. TYPE: VERT. CENT. RATING: 8400 GPM @ 152' HD. AND 1800 RPM TOTAL LOAD @ 4KV: 280 KW	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT.: 8 ⅛-CAP. TYPE: VERT. CENT. SINGLE STAGE RATING: 4500 GPM @ 750' HEAD & 1800 RPM TOTAL LOAD @ 4KV: 6400 KW	(CLASS II) CODE: ASME SECT VIII QUANT: 3 ⅓-CAP. TYPE: VERT. TURBINE WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARING SETTING: 60' RATING: 15,000 GPM @ 320' HEAD & 900 RPM TOTAL LOAD @ 4 KV: 3,390 KW
(D) IV SPRAY POND – RETENTION POND COMBINED FOR COOLING W/ RIVER USED FOR EMERG MAKEUP	SPRAY-RETEN. POND COMBINED (CLASS I) SPRAY POND SIZE: 700'x105'x7' DEEP VOL: 25x10³ CU YDS NO. SPRAY NOZZLES: (1408) 1½" SS RETENTION POND SIZE: 7' DEEP VOL: 40x10³ CU YDS	a SAME AS C-2a b SAME AS C-2b c EMERG MAKEUP PPS TRASH RACK (I) FLOW: 1000 GPM BARS: 2½"x½" – 3" c/c MIN. WTR LEVEL: 484' VEL. THRU BARS: .75 FPS	a SAME AS C-3a b SAME AS C-3b c EMERG MAKEUP PP STRUCT (I) SIZE: 10'x15'x10' H OPERATING FL. EL.: 550' BOTTOM OF PIT EL.: 475' TRAV. SCREENS QUANT: 2 (SPLASH-PROOF) SIZE: ... FRAME: 2-POST TOTAL LOAD @ 460 V: 3 KW	SAME AS C-4	SAME AS C-5	SAME AS C-6
(E) V MECH. DRAFT CT FOR COOLING W/ RETEN POND USED FOR EMERG MAKEUP	RETENTION POND (CLASS I) SIZE: 10' DEEP MAX. VOL: 65x10³ CU YDS	a SAME AS C-2a b SAME AS C-2b c SAME AS C-2c	a SAME AS C-3a b SAME AS C-3b c SAME AS C-3c	(CLASS I) CODE: ASME SECT VIII QUANT: 2 FULL-CAP. TYPE: VERT. CENT. RATING: 2000 GPM @ 180' HEAD & 1800 RPM TOTAL LOAD @ 4KV: 340 KW	SAME AS C-5	SAME AS C-6
(F) VI MECH. DRAFT CT FOR COOLING W/ HYP. CT BASIN USED FOR EMERG MAKEUP	RETENTION POND (CLASS II) SIZE: 10' DEEP MAX. VOL: 65x10³ CU YDS	a SAME AS C-2a b SAME AS C-2b c N/R	a SAME AS C-3a b SAME AS C-3b c N/R	SAME AS E-4	SAME AS C-5	SAME AS C-6
(G) VII MECH. DRAFT CT FOR COOLING W/ RIVER USED FOR EMERG MAKEUP	RETENTION POND (CLASS II) SIZE: 10' DEEP MAX. VOL: 65x10³ CU YDS	a SAME AS C-2a b SAME AS C-2b c EMERG MAKEUP PPS TRASH RACK (I) FLOW: 1000 GPM BARS: 2½"x½" – 3" c/c MIN. WTR LEVEL: 484' VEL. THRU BARS: .75 FPS	a SAME AS C-3a b SAME AS C-3b c SAME AS D-3c	SAME AS E-4	SAME AS C-5	SAME AS C-6
(H) VIII UNIT 1 HYP. CT FOR COOLING W/ UNIT 2 HYP. CT BASIN USED FOR EMERG MAKEUP	RETENTION POND (CLASS II) SIZE: 10' DEEP MAX. VOL: 65x10³ CU YDS	a SAME AS C-2a b SAME AS C-2b c N/R	a SAME AS C-3a b SAME AS C-3b c N/R	SAME AS E-4	SAME AS C-5	SAME AS C-6

ALTERNATES	7 SCREEN WASH PUMPS	8 EMERG MAKEUP PUMPS	9 MECH. DRAFT COOLING TOWER	10 ESW PIPING PIPE: B31.1 (CLASS I)***	11 RHRSW PIPING PIPE: B31.7 (CLASS I)***	12 EMERG M/U PIPING PIPE: B31.7 (CLASS I)***	13 MAKEUP PIPING PIPE: B31.1 (CLASS II)***	14 REMARKS
(A) I	(CLASS I) CODE: ASME SECT. III, CLASS III NUC. QUANT: 2 FULL-CAP. TYPE: VERT. TURBINE, WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARINGS SETTING: 80' RATING: 200 GPM @ 300' HEAD & 1800 RPM TOTAL LOAD @ 460 V: 20 KW	NOT REQUIRED (N/R)	NOT REQUIRED (N/R)	PRIMARY RATING: 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 6,500'	PRIMARY RATING 300 PSIG @ 850°F C.S. SIZE / LENGTH 48" / 5,800' 24" / 2,600' 18" / 10,400'	NOT REQUIRED (N/R)	PRIMARY RATING 125 PSIG @ 125°F C.S. SIZE / LENGTH 36" / 5,800' OR 48" / 2,900' FOR ESTIMATING USE WHICHEVER HIGHER IN COST	INPUT FOR MONTOUR INTAKE BY CIVIL. WITH THE MONTOUR INTAKE ARRANGEMENT ALL PUMPS TAKING SUCTION FROM RIVER ARE TO BE HOUSED IN STRUCTURES LOCATED AT THE RIVER IN ORDER TO AVOID DEEPER EXCAVATIONS THAT WOULD OTHERWISE BE REQUIRED. FOR ESTIMATING PIPING COSTS WITH THE MONTOUR TYPE INTAKE – WHERE APPLICABLE – DELETE OUTDOOR SUCTION PIPING SHOWN FOR CASE ALTERNATE AND INCREASE DISCH. PIPING LENGTH ACCORDINGLY
(C) III	NOT REQUIRED (N/R)	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT.: 2 FULL-CAP. TYPE: VERT. CENT RATING: 1500 GPM @ 100' HEAD & 1800 RPM TOTAL LOAD @ 460 V: 40 KW	N/R	PRIMARY RATING: 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 4,500'	PRIMARY RATING 300 PSIG @ 850°F C.S. SIZE / LENGTH 48" / 100' 36" / 200' 24" / 3,000' 18" / 5,200' 20" / 1,720' 4" / 2,600' 16" / 20,500'	PRIMARY RATING 150 PSIG @ 500°F C.S. SIZE / LENGTH 12" / 50' 10" / 2,400'	PRIMARY RATING 125 PSIG @ 125°F SIZE / LENGTH 36" / 11,600' OR 48" / 5,800' FOR ESTIMATING USE WHICHEVER HIGHER IN COST	SAME AS A-14 WHERE APPLICABLE
(D) IV	N/R	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT: 2 FULL-CAP. TYPE: VERT. TURBINE WET PIT, OPEN LINESHAFT W/ PRELUBRICATION OF COL. BEARINGS RATING: 1000 GPM @ 320' HEAD & 1800 RPM TOTAL LOAD @ 460 V: 70 KW	N/R	PRIMARY RATING: 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 4,500'	SAME AS C-11	PRIMARY RATING 150 PSIG @ 500°F C.S. SIZE / LENGTH 10" / 5,800' 8" / 5,000'	SAME AS C-13	SAME AS A-14
(E) V	N/R	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT: 2 FULL-CAP. TYPE: VERT. CENT. RATING: 1600 GPM @ 120' HEAD & 1800 RPM TOTAL LOAD @ 460 V: 50 KW	(CLASS I) QUANT.: ONE (1) ... SIZE: ... DESIGN DATA: FLOW: 44,000 GPM Twb: 80°F APPROACH: 10°F COOLING RANGE: 40 TOTAL LOAD (FAN) @ 460 V: 450 KW	PRIMARY RATING: 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 2,800'	PRIMARY RATING 300 PSIG @ 850°F C.S. SIZE / LENGTH 48" / 50' 24" / 1,800' 18" / 3,200'	SAME AS C-12	SAME AS C-13	SAME AS A-14 WHERE APPLICABLE
(F) VI	N/R	N/R	SAME AS E-9 NOTE: STATION HYP. CT BASINS ONLY TO BE CHANGED FROM CLASS II TO CLASS I	PRIMARY RATING 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 2,300'	SAME AS E-11	PRIMARY RATING 150 PSIG @ 500°F C.S. SIZE / LENGTH 10" / 1200'	SAME AS C-13	SAME AS A-14 WHERE APPLICABLE
(G) VII	N/R	(CLASS I) CODE: ASME SECT III CLASS III NUC. QUANT.: 2 FULL-CAP. TYPE: VERT. TURBINE WET PIT, OPEN LINESHAFT W/ PRELUBRICATION ... SETTING: 80' RATING: 1000 GPM @ 300' & 1800 RPM TOTAL LOAD @ 460 V: 125 KW	SAME AS E-9	PRIMARY RATING 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 2,800'	SAME AS E-11	PRIMARY RATING 150 PSIG @ 500°F C.S. 12" / 5800' 16" / 5000'	SAME AS C-13	SAME AS A-14
(H) VIII	N/R	N/R	MECH. DRAFT CT: N/R NOTE: STATION NAT. DRAFT COOLING TOWERS TO HAVE CLASS I BASINS. UNIT 1 TOWER, IN ADDITION, TO BE CLASS I ABOVE BASIN BUT NOT TORNADO PROOF. TOWER BASINS EACH TO INCREASE BY ~25% IN VOLUME	PRIMARY RATING: 150 PSIG @ 500°F C.S. SIZE / LENGTH 20" / 2,800'	SAME AS E-11	SAME AS F-12	SAME AS C-13	SAME AS A-14 WHERE APPLICABLE

* "PLANT" MAKEUP PUMPS SUPPLYING MAKEUP WATER TO HYPERBOLIC COOLING TOWERS

... LAND AREA; HENCE, NOT INCLUDED IN MATRIX

a – REFERS TO ESW & RHRSW   b – REFERS TO PLANT MAKEUP WATER   c – REFERS TO ESW & RHRSW MAKEUP

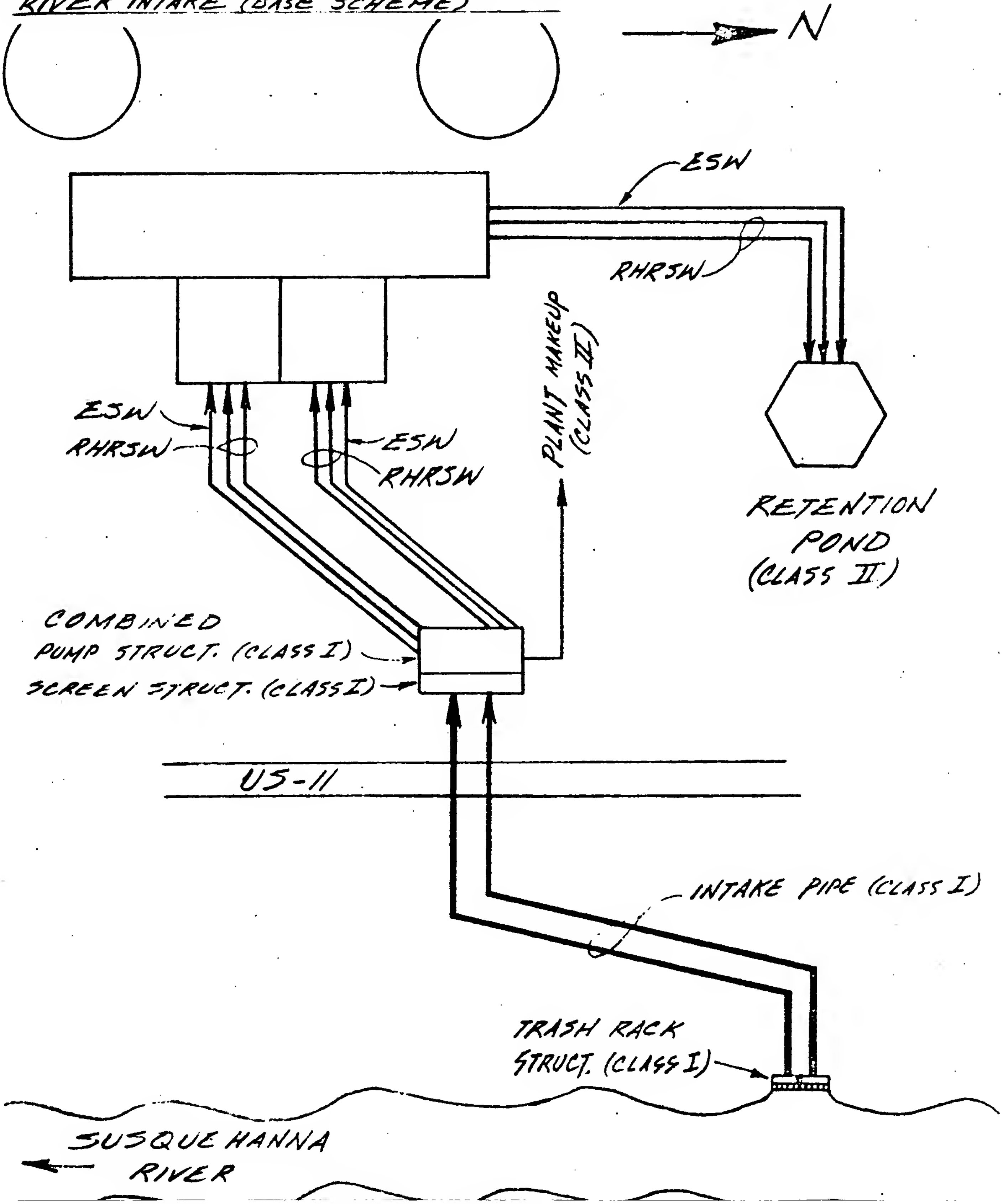
REVISION: 1
DATE: 8/9/71

CALCULATION SHEET ECL 217

ER T. NAGHDI DATE 8-2-71 CHECKER DATE

LE PP&L CO. SSES, UNITS 1&2 JOB NO. 8856

CT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY - ALT. I, A, SHEET NO. 1/10
RIVER INTAKE (BASE SCHEME)



CALCULATION SHEET

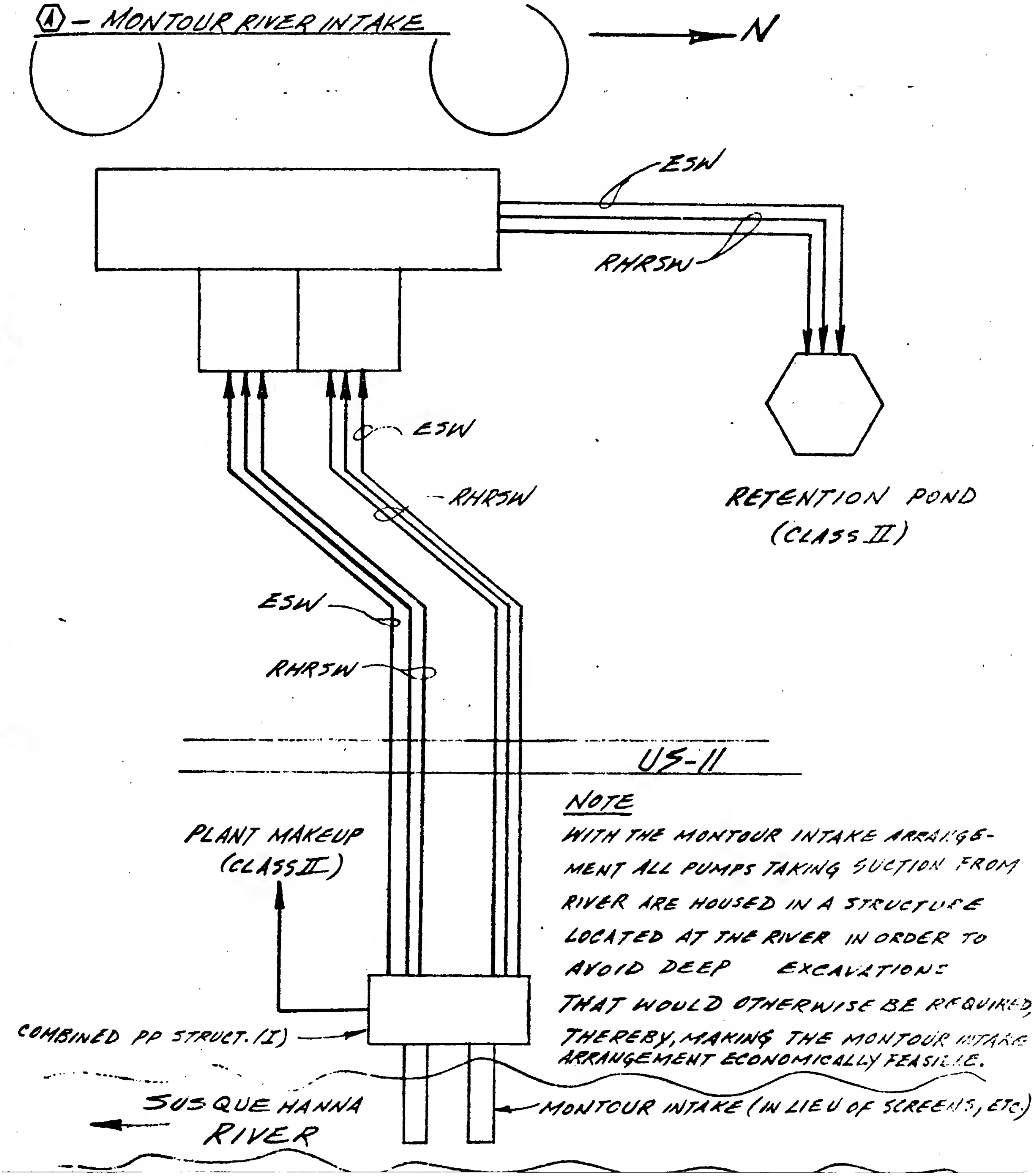
ECL 217

ENGINEER T. NAGHDI DATE 8-2-71 CHECKER ______ DATE ______

TITLE PP&L Co. SSES, UNITS 1 & 2 JOB NO. 8856

SUBJECT ENGINEERED SAFEGUARD EQUIP SERV WTR STUDY - ALT. I, SHEET NO. 2/10

(A) - MONTOUR RIVER INTAKE



NOTE

WITH THE MONTOUR INTAKE ARRANGEMENT ALL PUMPS TAKING SUCTION FROM RIVER ARE HOUSED IN A STRUCTURE LOCATED AT THE RIVER IN ORDER TO AVOID DEEP EXCAVATIONS THAT WOULD OTHERWISE BE REQUIRED, THEREBY, MAKING THE MONTOUR INTAKE ARRANGEMENT ECONOMICALLY FEASIBLE.

intake pipes are placed on sand bedding at river bottom and covered with a thick layer of crushed rock for proper filtration.

Alternate II, a cooling pond concept, was rejected from detailed evaluation early in the study due to a non-availability of suitable land area.

In lternate III, a Class I pond with fixed spray piping is utilized as the ultimate heat sink. The existing retention pond is employed as the source of emergency makeup water to the spray pond as shown in Fig. 3-2, p. 22.

The spray pond configuration is rectangular, long and narrow to increase the air area as a safeguard against abnormally low wind velocities. To improve its performance, it is placed with its long axis perpendicular to the prevailing summer wind at the site.

The E.S.S.W. pumps are housed in a Class I pump structure located between the spray pond and the main building. The E.S.S.W. pumps take water from the spray pond through fixed screens and supply cooling water to the respective heat transfer apparatus. The spent cooling water is then returned to the pond spray system and cooled by evaporative cooling.

Emergency makeup pumps draw water from the retention pond through fixed screens to replenish the evaporative and drift losses in the spray pond.

Note that because the E.S.S.W. systems are not normally operating, the spray pond is essentially stagnant and, therefore, subject to freezing during cold weather periods. Direct injection of waste heat into the pond with proper distribution will provide freeze protection.

Alternate IV employs a combined spray pond-retention pond as the ultimate heat sink as shown in Fig. 3-3, p 23. The pond has a fixed spray system with an emergency makeup capability from the river.

The combined spray pond-retention arrangement does not require freeze protection because of continuous blowdown from the hyperbolic cooling towers to the combined pond. The combined pond is as long as the spray pond employed in Alternate III but approximately three times as wide. Also, by making the combined pond wider (not shown rectangular in Fig. 3-3 only to retain the symbol used for denoting the retention pond) the drift losses are reduced. This is due to increased distances between outer spray nozzles and the sides of the pond.

The pond spray system employs six (6) independent main headers, consisting of our RHRSW and two ESW lines. Independent headers

26

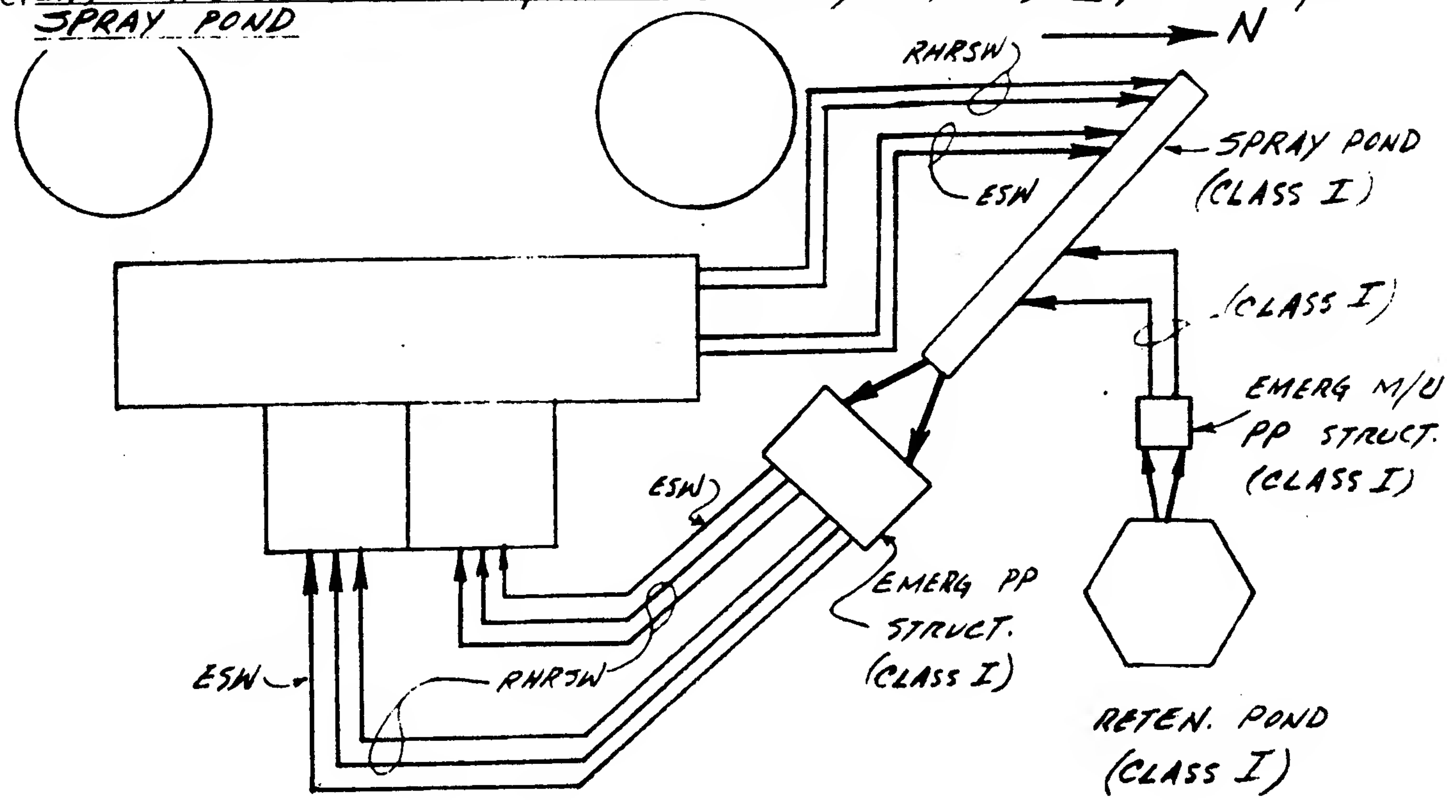
CALCULATION SHEET

ECL 217

DESIGNER T. NAGHDI DATE 8-2-71 CHECKER ______ DATE ______

TITLE PP&L CO. SSES, UNITS 1 & 2 JOB NO. 8856

SUBJECT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY - ALT. III, ©, SHEET NO. 3/10
SPRAY POND



US-11

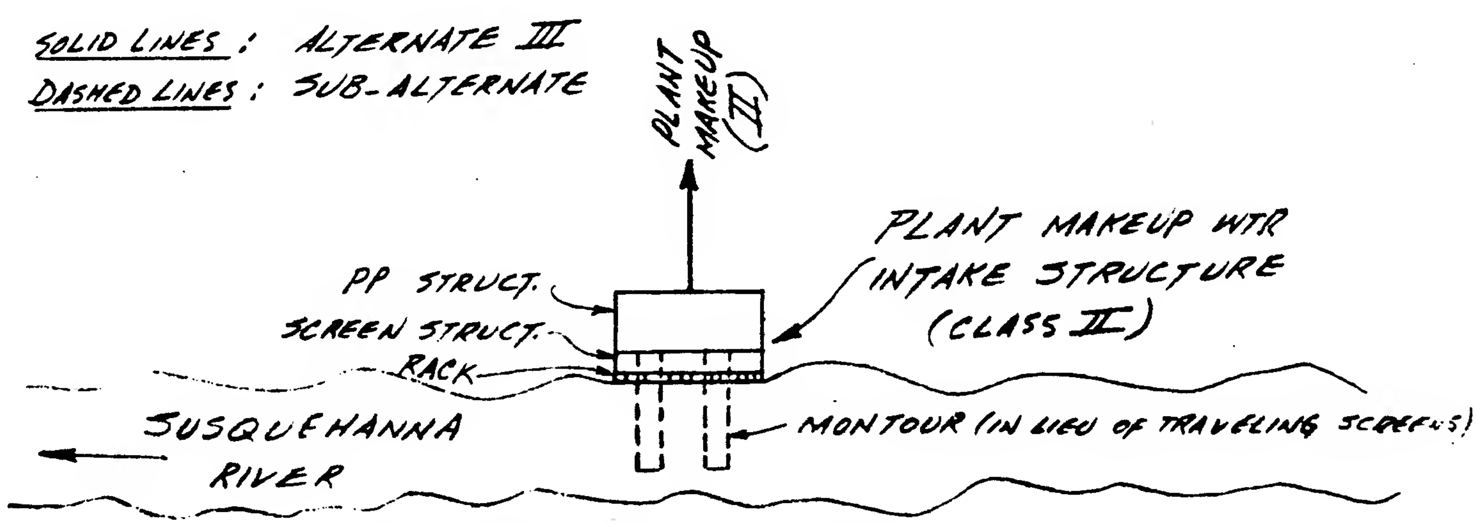


FIGURE 3.0 - SPRAY POND

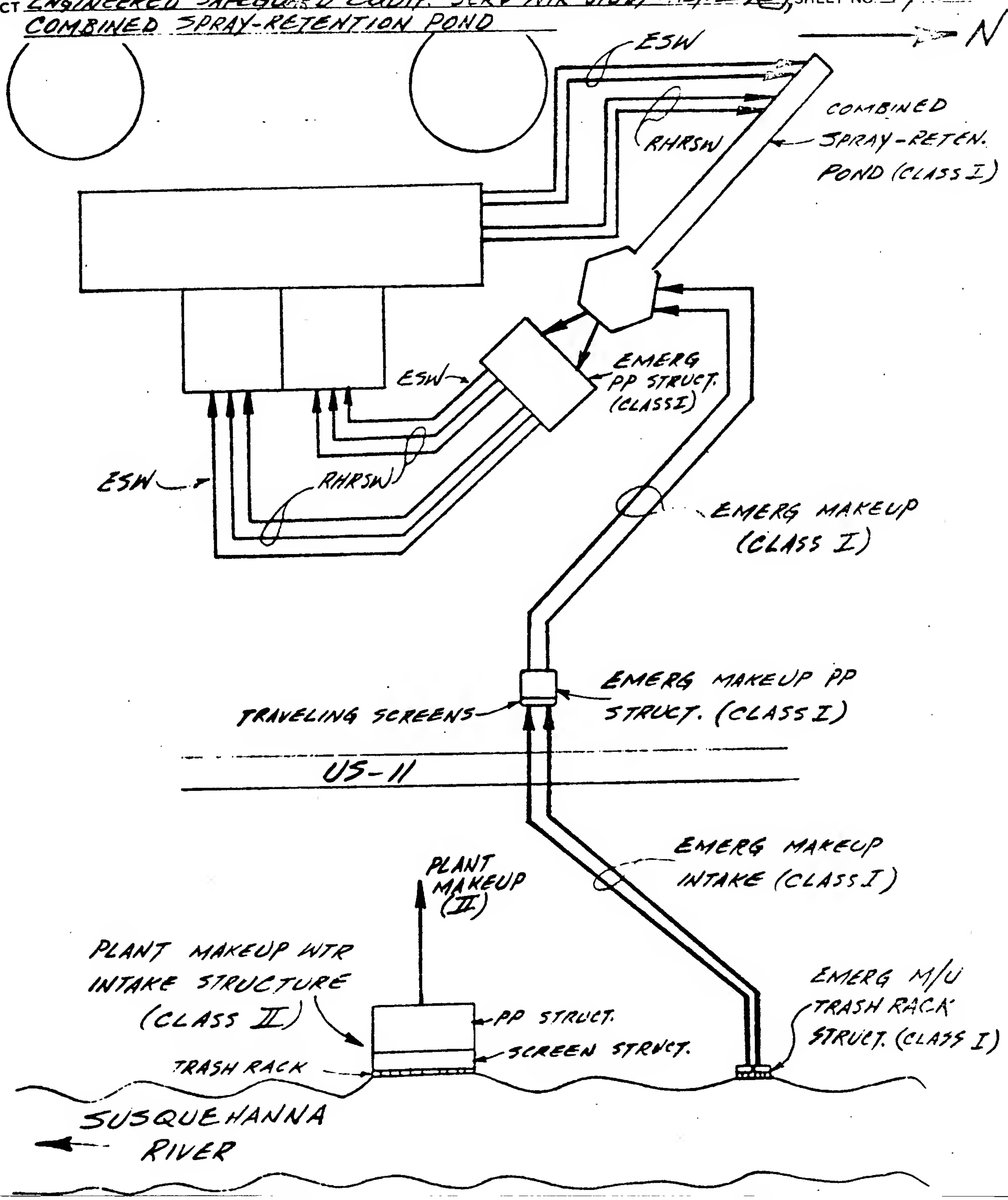
CALCULATION SHEET

ECL 217

DESIGNER T. NAGHDI DATE 8-2-71 CHECKER ______ DATE ______

TITLE PP&L Co. SSES, UNITS 1&2 JOB NO. 8856

SUBJECT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY-ALT. IV, D, SHEET NO. 4/10
COMBINED SPRAY-RETENTION POND



are provided to comply with the redundancy required by the P.S.A.R. A series of branch headers emanating from each main header distribute the spent cooling water through a multitude of hollow cone spray nozzles projecting above the pond surface. With a rectangular combined pond spray,nozzles producing finer spray drops could be used to increase the spray system efficiency (as opposed to coarser spray drops required in Alternate III to minimize drift losses), since drift loss will be reduced with this arrangement.

Economics and interpretation of the AEC draft criteria received prior to the completion of this study required that this alternate be further evaluated on the basis of no separate emergency makeup requirements from the river, assuming that the retention pond would have adequate volume for 30 days operation without replenishment. This subalternate is designated IVa.

In Alternate V, a Class I mechanical draft cooling tower is used as the ultimate heat sink. The existing retention pond, modified to meet the Class I requirements, is employed as the source of emergency makeup water as shown in Fig. 3-4, p. 25.

The pump structure housing the ESSW pumps is located in the upper site areas near the mechanical draft cooling tower. The pumps take water from the tower basin and supply cooling water to the respective heat transfer apparatus. The spent cooling water is then returned to the tower where it is cooled by evaporative cooling and collected in the basin.

In Alternate VI, the mechanical draft cooling tower of Alternate V is used as the ultimate heat sink, but emergency makeup water is supplied from the basins of the existing natural draft or hyperbolic cooling towers as shown in Fig. 3-5, p. 26. Note that for Alternate VI, the basins of the hyperbolic towers are modified to meet the Class I criteria.

In this scheme the ESSW system is divorced from the existing retention pond. This pond remains a Class II structure to perform the function for which it was originally designed.

In Alternate VII, the mechanical draft cooling tower of Alternate V is used as the ultimate heat sink. This arrangement is the same as that described for Alternate V except for the emergency makeup water system, which is supplied from the Susquehanna River as shown in Fig. 3-6, p. 27.

In Alternate VIII the Unit 2 hyperbolic cooling tower is used as the ultimate heat sink and the Unit 1 hyperbolic tower basin is employed as the source of emergency makeup water as shown diagrammatically in Fig. 3-7, p. 28. To assure an ample supply of makeup water for a 30-day cooldown, the water holding capacity of both basins is increased by approximately 25%. The

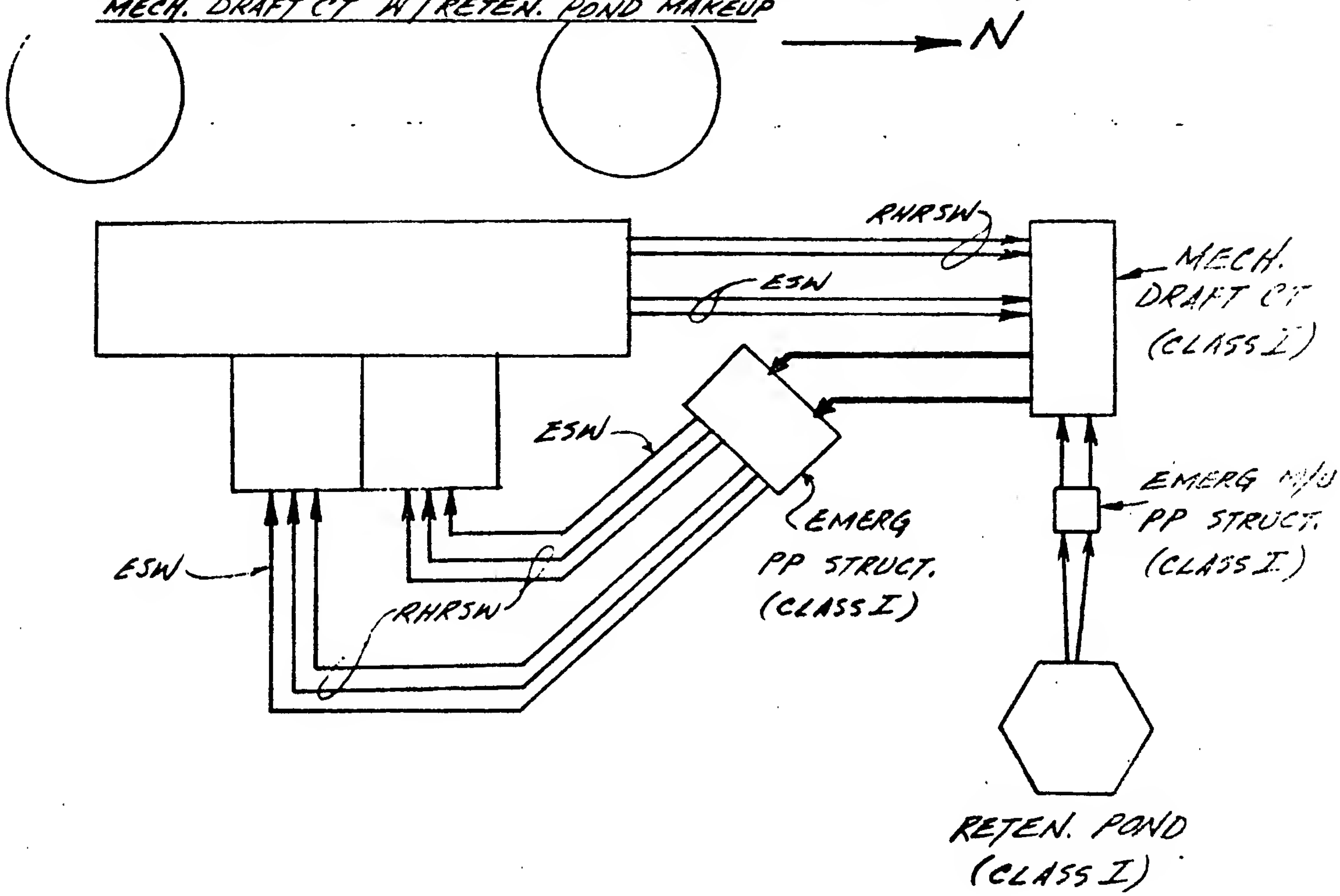
CALCULATION SHEET

ECL 217

SIGNER T. NAGHDI DATE 8-2-71 CHECKER DATE

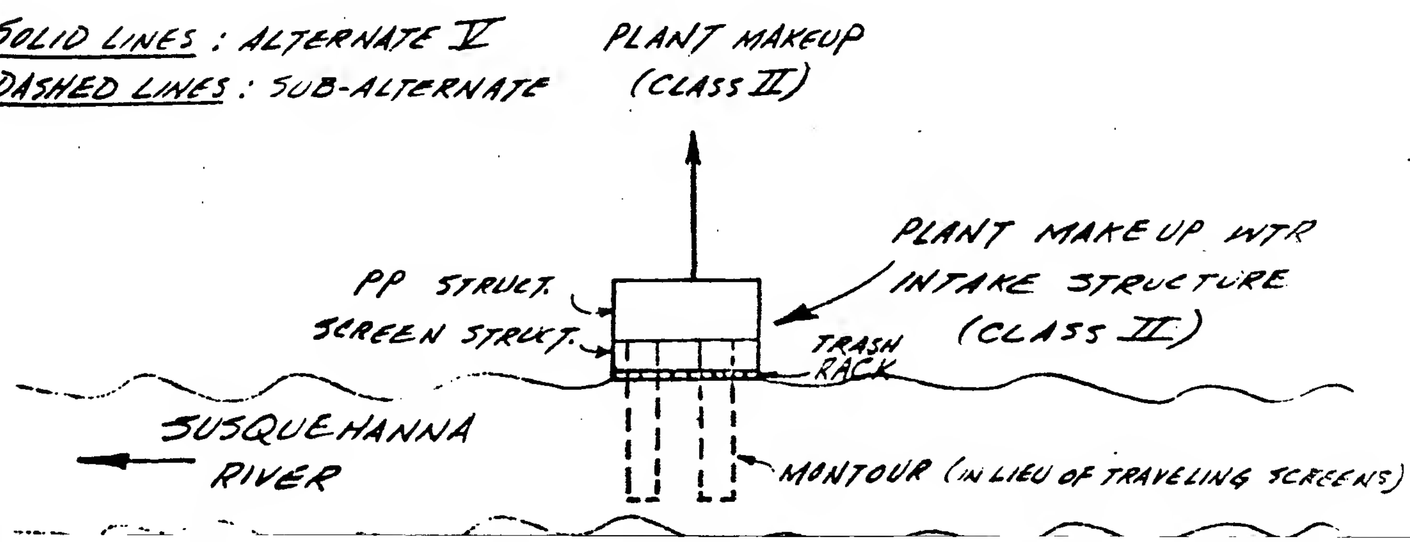
TITLE PP&L CO. SSES, UNITS 1&2 JOB NO. 8856

SUBJECT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY-ALT. V, (E), SHEET NO. 6/10
MECH. DRAFT CT W/RETEN. POND MAKEUP



US-11

SOLID LINES : ALTERNATE V
DASHED LINES : SUB-ALTERNATE



BECHTEL

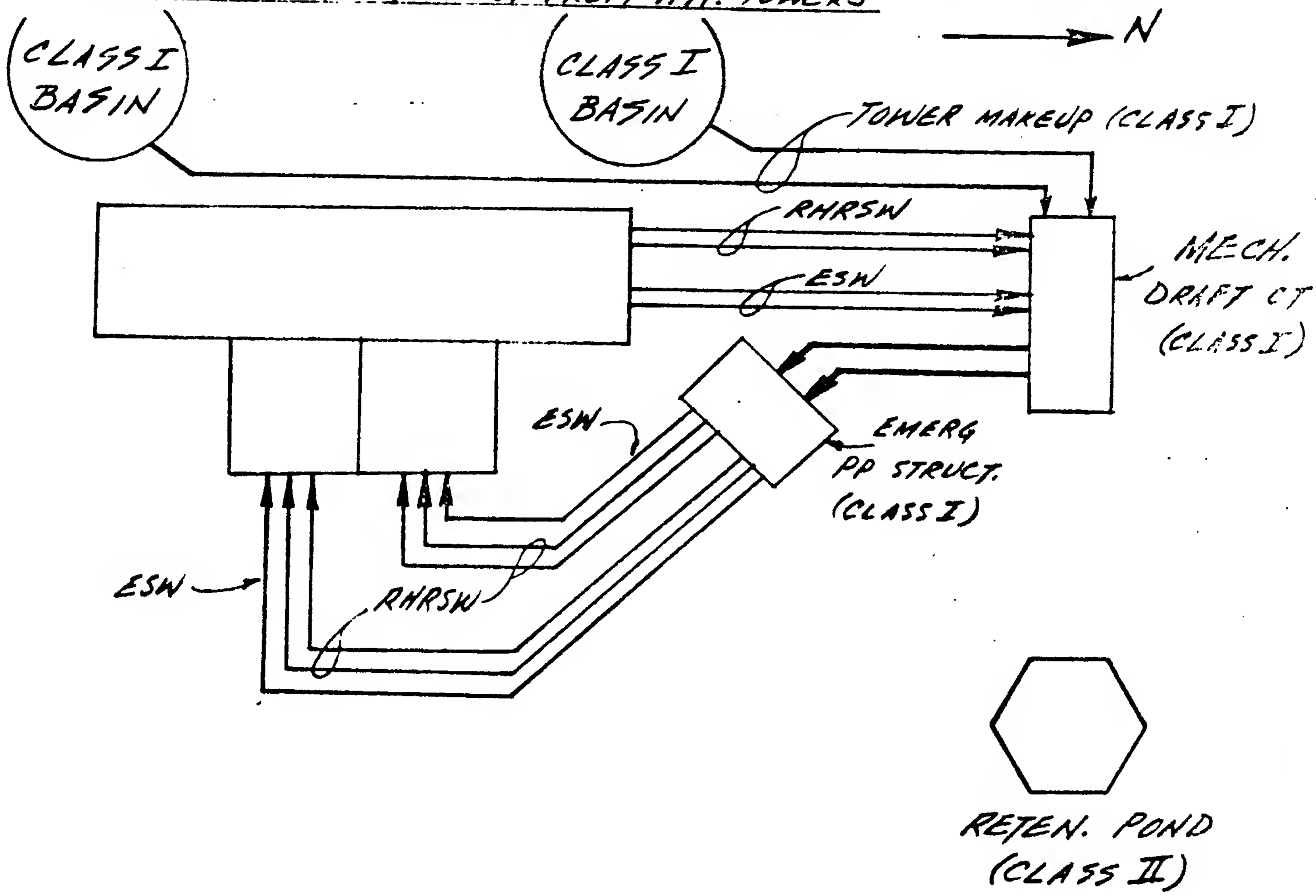
CALCULATION SHEET

ECL 217

DESIGNER T. NAGHDI DATE 8-2-71 CHECKER DATE

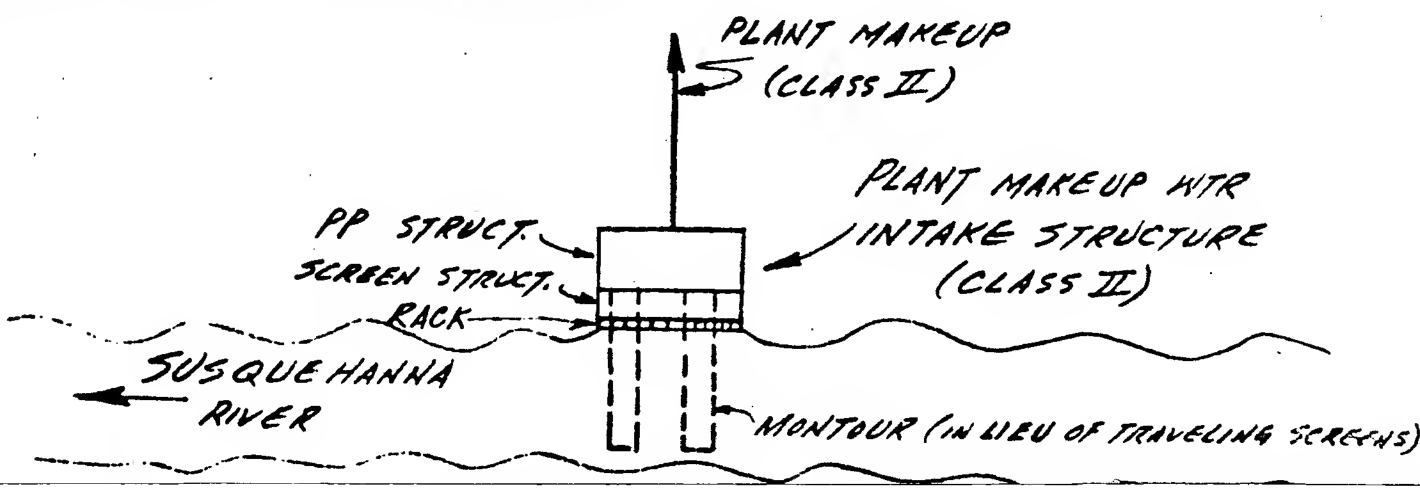
TITLE PP&L CO. SSES, UNITS 1&2 JOB NO. 8856

BRIEF ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY - ALT. VI, (F), SHEET NO. 7/10
MECH. DRAFT CT W/MAKEUP FROM HYP. TOWERS



US-11

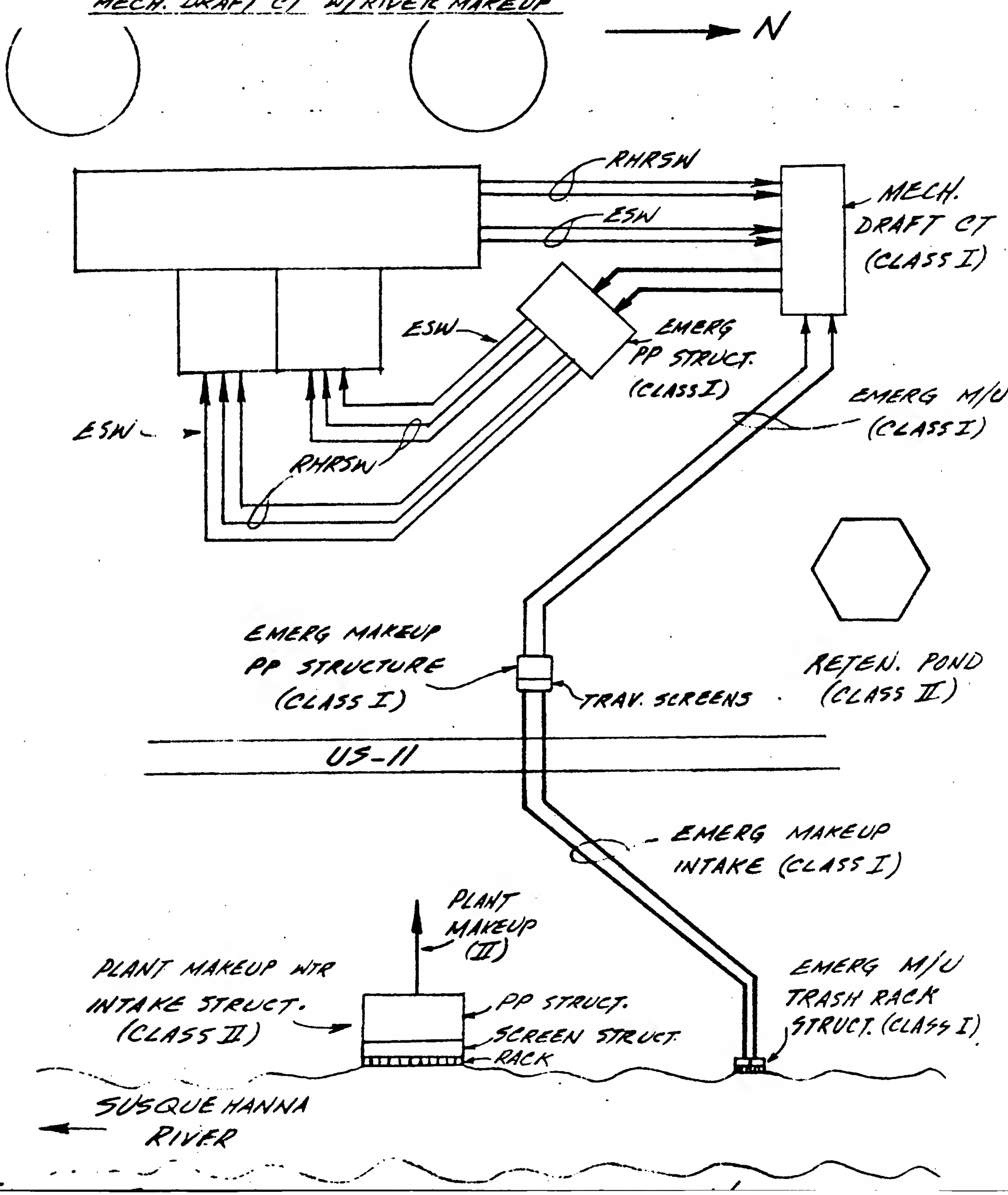
SOLID LINES : ALTERNATE VI
DASHED LINES : SUB-ALTERNATE



[...]NER T. NAGHDI DATE 8-2-71 CHECKER ______ DATE ______

[...]TLE PP&L Co. SSES, UNITS 1&2 JOB NO. 8856

[...]JECT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY - ALT. VII, (G), MECH. DRAFT CT W/RIVER MAKEUP SHEET NO. 8/10



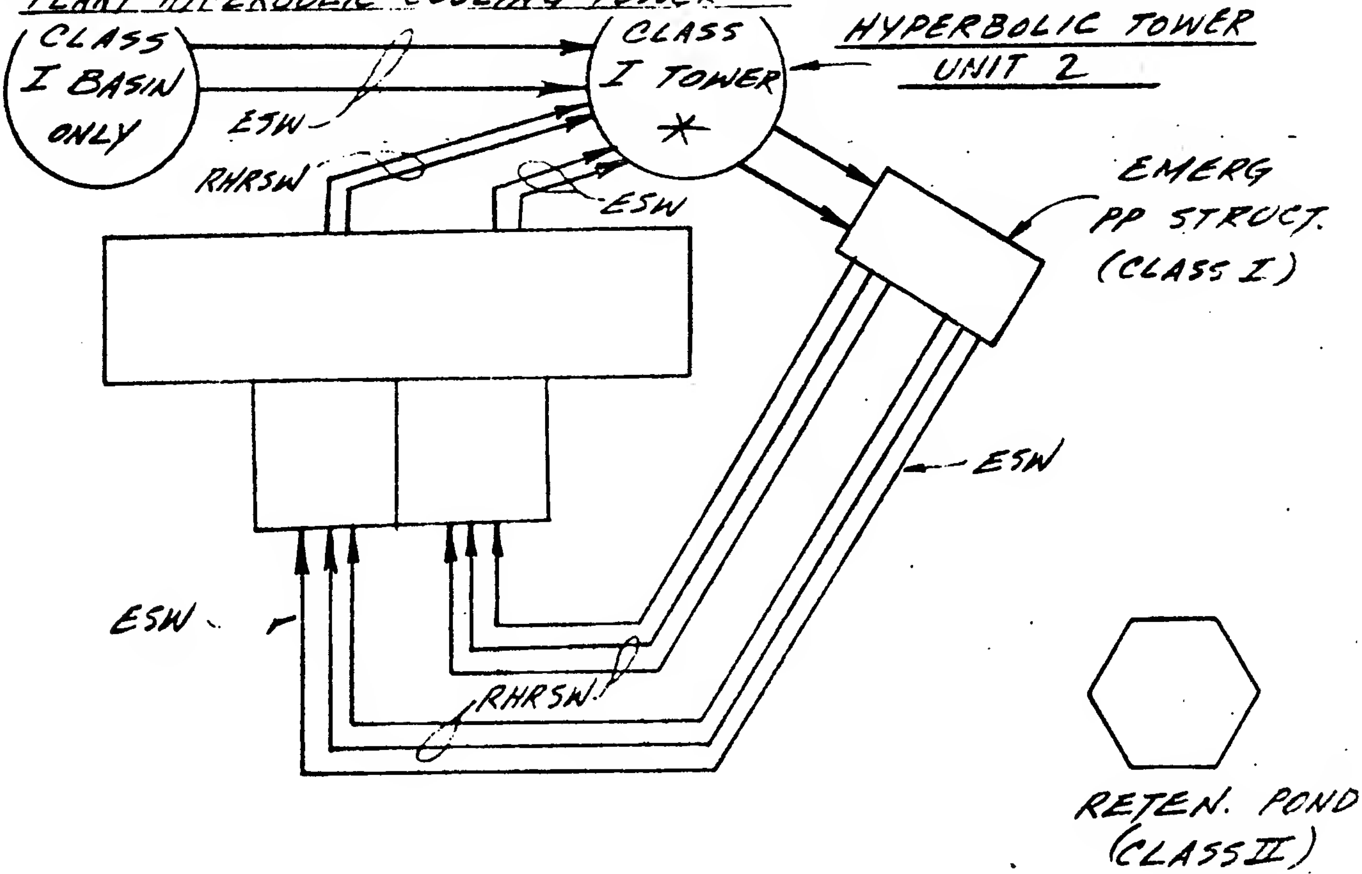
ECL 217

[?]ECHTEL

[DES]IGNER T. NAGHDI DATE 8-2-71 CHECKER ______ DATE ______

TITLE PP&L Co. SSES, UNITS 1&2 JOB NO. 8856

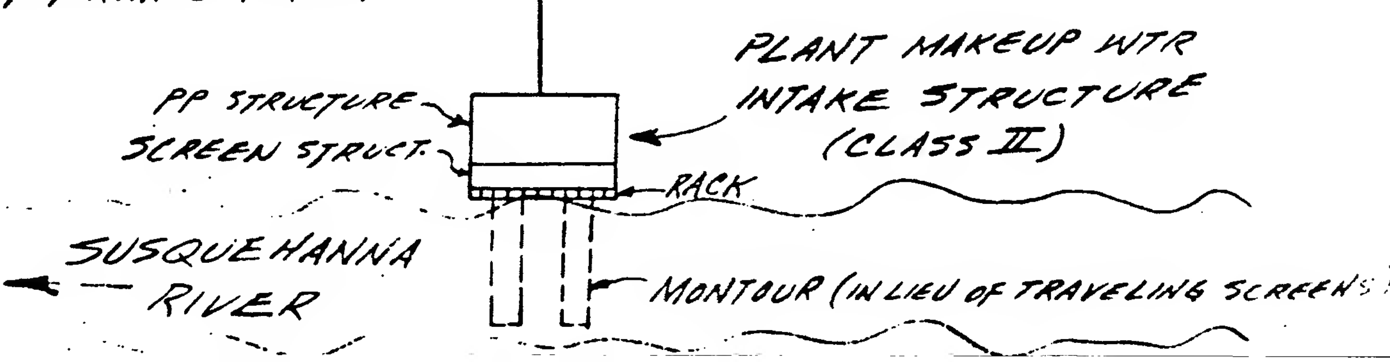
[SUB]JECT ENGINEERED SAFEGUARD EQUIP. SERV WTR STUDY-ALT VIII, (H) SHEET NO. 10/10
PLANT HYPERBOLIC COOLING TOWER



US-11

SOLID LINES: ALTERNATE VIII
DASHED LINES: SUB-ALTERNATE

* COOLING TOWER SHELL IS NOT TORNADO-PROOF



Unit 2 tower and the basin of the Unit 1 tower are modified to meet the Class I criteria. The Unit 2 hyperbolic tower in this alternate is completely modified to meet the Class I criteria, except that the shell is not tornado proof. A check with several manufacturers of natural draft cooling towers showed their reluctance to seriously consider the tornado proofing of the shell.

The ESSW pumps take water from the basin of Unit 2 tower and supply cooling water to the respective heat transfer apparatus. The spent cooling water is then returned to the tower. Makeup water to replenish evaporative and drift losses is provided by gravity from the basin of the Unit 1 cooling tower.

3.3 Heat Load

The objective of the ESSW was to meet the original design requirements as well as to satisfy the AEC criteria pertaining specifically to licensing. One of the main considerations of cost and feasibility centered around the AEC criteria for safe shutdown of the plant reactor units.

These criteria require that an ultimate heat sink be available which is suitable for safe shutdown of both reactor units for a minimum period of 30 days without replenishment of water.

Fig. 3-8 shows the rate of decay heat generated by one reactor core as a function of time for the 30 day period following reactor shutdown. This figure is based on information supplied by General Electric on their boiling water reactor to be used in the Susquehanna project.

The average decay heat generation rate over the 30 day period is 40 x 10^6 Btu/hr., for each of the two reactors and is removed by the R.H.R.S.W. system. The E.S.W. system, which provides emergency cooling to the diesel generators and space cooling for the engineered safeguards equipment, adds an additional maximum heat load of approximately 60 x 10^6 Btu/hr. This results in an average total heat removal rate of 140 x 10^6 Btu/hr., and the total evaporative losses for the 30-day period have been determined on this basis for all of the alternatives.

The decay heat rate for one reactor, one hour after shutdown, is about 188 x 10^6 Btu/hr., declining rapidly thereafter. Since this provides substantial margin on the 140 x 10^6 Btu heat load, it has been used as the basis for cooling system selection purposes. However, it will be further reviewed during the final detailed design.

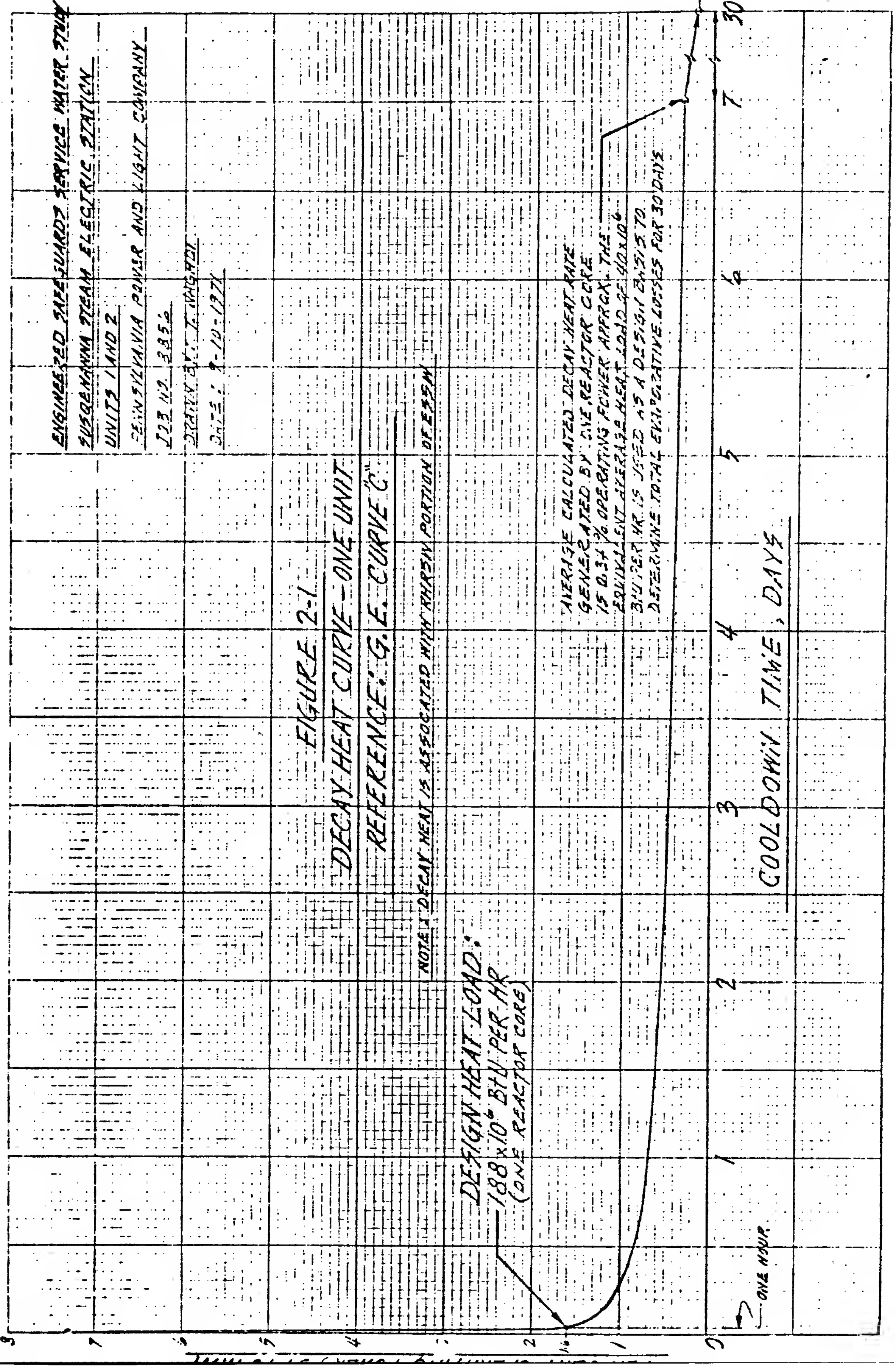

ENGINEERED SAFEGUARDS SERVICE WATER STUDY
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 AND 2
PENNSYLVANIA POWER AND LIGHT COMPANY
FIGURE 2-1
DECAY HEAT CURVE—ONE UNIT
REFERENCE: G.E. CURVE "C"
NOTE: DECAY HEAT IS ASSOCIATED WITH RHRSW PORTION OF ESSW
AVERAGE CALCULATED DECAY HEAT RATE GENERATED BY ONE REACTOR CORE IS 0.34% OPERATING POWER APPROX. THE EQUIVALENT AVERAGE HEAT LOAD OF 40x10^6 BTU PER HR IS USED AS A DESIGN BASIS TO DETERMINE TOTAL EVAPORATIVE LOSSES FOR 30 DAYS
DESIGN HEAT LOAD:
188x10^6 BTU PER HR
(ONE REACTOR CORE)
ONE HOUR
COOLDOWN TIME, DAYS
0
1
2
3
4
5
6
7
30

Fig. 3-8

3.4 Evaluation of the Alternatives

The knowledge of the AEC criteria on emergency cooling and Class I criteria plus the knowledge of the maximum heat load enabled Mr. Naghdi to evaluate the alternatives in terms of licensability and costs. The licensability was a crucial consideration, since the AEC has the final say in the operation of the plant by issuing or not issuing a final "operating permit", which is issued only after the AEC is thoroughly convinced that the plant conforms to all of their class specifications. The cost was considered to be important to Bechtel, even though this project was on a reimbursible (cost) contract with PP&L. It is generally considered that the architect-engineer has an ethical obligation to their client to not only furnish a working system that fulfills all of the clients specifications but to also furnish the least expensive acceptable system.

In evaluating the alternatives, the general cost trends of the various alternatives soon became apparent and Mr. Heisler sent an update of Bechtel's progress on the study to PP&L in August 1971 (Exhibit 3-1, p.32).Further study on the basic concepts of each alternative in terms of licensability was carried out and the extent of compliance with the AEC criteria is presented in tabular form in Table 3-2, p.34, "Licensability of Alternatives Considered."

During this same time, a cost evaluation of the various schemes was being put together. The order of magnitude cost differential with respect to the base scheme for each alternative is shown in Table 3-3, "Cost Differential". These incorporate the normal plant makeup water system, because it is inherent in the base scheme.

At the request of PP&L, an infiltration intake based on the Montour design, in lieu of a conventional intake, was later applied to each alternate considered. The order of magnitude cost differential for each of these was evaluated at the conclusion of the study based on facts developed during the study. On the basis of the study, four general conclusions were brought out: (1) all of the alternatives considered were technically feasible and could be constructed to satisfy existing requirements; (2) the alternates in which the ESSW pumps are located in the upper site area offer a distinct maintenance advantage over the base scheme. This location offers a substantial reduction in the standby diesel capacity over that required by the base scheme; (3) the licensability of Alternate VIII may be somewhat difficult, since a Class I cooling tower has never been built, and Bechtel was unable to get any of the cooling tower manufacturers to even bid on tornado proofing the shell, and (4) based on the most recent AEC criteria, Alternate IVa (no emergency makeup) is a satisfactory design, since the

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ECL 217

BECHTEL

COPY

bcc: J.B. Violette
J.D. Plawchan
H.N. Robey
J.T. Marvin
R.A. Schmitter
K.D. Peterson
A. Feugray

August 6, 1971

0261
KP

Pennsylvania Power & Light Co.
901 Hamilton Street
Allentown, Pennsylvania 18101

Attention: Mr. W.A. Frederick

Subject: Susquehanna Steam Electric Station Units 1 and 2
Job 8856
Emergency Service Water Study
BLP-307

Dear Bill:

We have been asked to provide a brief update of the status of our work on the study of various Emergency Service Water Systems alternates being evaluated.

As you know, we are looking at seven (7) alternates covering a mixture of intake sources for this service either at the river or from an impounded source on the upper site area, together with a variety of cooling methods including mechanical and natural draft towers and spray ponds. Our work is almost complete and we are now engaged in our final cost and technical reviews of the study.

We find that the alternates appear to be ranking themselves as follows, the alternates below are arranged in groups of ascending cost.

a) Lowest Cost Alternates: Spray pond with retention pond makeup source: Class I natural draft tower with makeup from the second Class II natural draft tower having a Class I basin.

b) Middle Cost Alternates: Mechanical draft towers taking makeup either from the river, the retention pond or a Class II natural draft tower with a Class I basin.

c) Highest Cost Alternates: Once through cooling with river intake (PSAR basis); spray pond using river makeup.

EXHIBIT 3-1

The groupings above represent the general way in which the costing of the alternates is developing. We are also costing for each of the alternates the use of a Montour type infiltration intake, sized to provide the necessary capacity for each system and this will be included in the final costing and ranking of the alternates. In addition there are technical considerations which we are refining; this may modify somewhat the groupings.

Following submittal of the study and after you have had time for your inhouse reviews, we recommend a meeting to discuss the study and following that, that it be discussed with the AEC (DRL) to assure their agreement before submitting a PSAR amendment.

We are hoping to complete the study and have it in your hands a specific recommendation within the next two weeks.

Very truly yours,

S. I. Heisler
Project Engineer

SIH:mt
cc: Mr. John F. West, Jr.

EXHIBIT 3-1

TABLE 3-2

LICENSABILITY OF ALTERNATES CONSIDERED

Makeup Sources	Earthquake	Tornado	Hurricane	Flood	Drought	Other	Water Borne Accident	Failure of Structure
River Pump House	X	X	X	*O	O	X	*O	X
Retention Pond	X	O	X	X	X	X	X	X
CT Basin	*X	*O	X	X	X	X	X	X
Heat Rejection Mechanism								
Mech. Draft CT	X	*X	X	X	X	X	X	X
Spray Pond	X	X	X	X	X	X	X	X
Once thru using the river	X	X	X	*X	*X	X	*O	X
Existing Hyperbolic CT	X	*O	X	X	X	O	X	O

X Satisfies Criterion

* High Potential Cost adder

O Open for interpretation and further definition

ECL 217

TABLE 3-3

COST DIFFERENTIAL

$ in Parentheses are for alternates with Montour Intake

Alternate	Differential Cost $\$ x10^6$		Identification UHS/EMU Source
I	Base	(+3.4)	Susquehanna River/None
III**	-2.4	(-0.8)	Spray Pond/Retention Pond
IV	-0.6	(+4.1)	Combined Spray Pond-Retention Pond/River
IVa***	-2.9	(-1.3)	Combined Spray Pond-Retention Pond/None
V	-1.0	(+0.5)	Mech. Draft CT/Retention Pond
VI	-0.6	(+0.9)	Mech. Draft CT/Hyperbolic CT Basins
VII	+0.9	(+5.7)	Mech. Draft CT/Susquehanna River
VIII	-2.4	(-0.9)	Unit 2 Hyperbolic CT/Unit 1 Hyperbolic CT Basin

* UHS: ultimate heat sink; EMU: emergency makeup

** Alternate II, a Cooling Pond concept, at onset was considered "not feasible" due to nonavailability of suitable land area.

*** Differential costs for Alternate IVa (no emergency makeup capability) and its sub-alternate.

volume of the combined spray and retention pond is adequate for 30 days. The order of magnitude cost differential for Alternate IVa, as noted in Table 3-3, is $2,900,000 below the base scheme, making this alternative economically more attractive than all the other alternatives considered.

3.5 Conclusions

The results of Table 3-2 and 3-3 are condensed into Table 3-4, p. 37, along with their rankings of preference. These conclusions and results are the basis for five recommendations made at the end of the study submitted to Mr. Heisler in October 1971. The recommendations are as follows:

(1) Adopt Alternate IVa as the baseline design,
(2) Prepare a presentation to the AEC to be presented immediately,
(3) Begin detailed subsurface work in the spray pond/retention pond area,
(4) Begin detailed design work on the "upper site" portion of the system,
(5) Prepare alternate designs and refine the cost estimates for both conventional and infiltration intakes on the Susquehanna River.

As a result of the recommendations of the study, Mr. Heisler sent the study along with the letter shown in Exhibit 3-2, p. 38, to PP&L in the middle of October 1971.

TABLE 3-4

RANK	ALTERNATE	DIFFERENTIAL COST $\$x10^6$	*TECHNICAL/ LICENSABILITY CONSIDERATIONS	IDENTIFICATION
1	IVa**	-2.9	X/X	Combined Spray Retention Pond w/o Makeup
2	III	-2.4	X/X	Spray Pond w/Retention Pond Makeup
3	IV	-0.6	X/0	Combined Spray Pond-Retention Pond w/River Makeup
4	V	-1.0	D/X	Mech. Draft CT w/Retention Pond Makeup
5	VI	-0.6	D/X	Mech. Draft CT w/Hyperbolic CT Basin Makeup
6	I	Base	X/0	Once Thru (River)
7	VII	0.9	D/0	Mech. Draft CT w/River Makeup
8	VIII	-2.4	D/D	Existing Hyperbolic CT

*D Relative degree of technical difficulty associated with final design

X No difficulties anticipated

O Open for interpretation and further definition

** Alternate IVa was developed as a result of reviewing Alternates III and IV and optimizing costs developed for a scheme which satisfies all criteria with the lowest overall cost.

NOTE: An infiltration (Montour type) intake would add from $1,400,000 to $4,700,000 to the system selected.

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T. Keihl

October 14, 1971

Pennsylvania Power & Light Company
901 Hamilton Street
Allentown, Pennsylvania 18101

Attention: Mr. W. A. Frederick

Subject: Susquehanna Steam Electric Station, Units 1 and 2
Job 8856
Engineered Safeguards Service Water Study
BLP-432

Dear Bill:

Enclosed are three (3) copies of the subject study for your review and comment. The resulting recommendations are contained in Section 2 and listed below:

- Adopt Alternate IVa (Combined Spray-Retention Pond w/o Makeup) as the baseline design to be utilized for SSES.
- Prepare a presentation to the AEC/DRL. (NOTE: Presentation made to AEC/DRL on September 30, 1971.)
- Begin detailed subsurface work in the spray pond/ retention pond area.
- Begin detailed design work on the "upper site" portion of the system.
- Prepare alternate designs and refine the cost estimates for both conventional and infiltration intakes on the Susquehanna River.

With the submission of this study, we are requesting your necessary approval to proceed with the detailed design of the recommended alternate, and desire such approval no later than October 29, 1971.

Very truly yours,

S. I. Heisler
Project Engineer

KDP:dc

4. AEC INVOLVEMENT

4.1 AEC Safety Guide

While work at Bechtel was progressing on the alternate methods for the Residual Heat Removal Service Water (RHRSW) system, the Atomic Energy Commission was busy preparing a safety guide with regard to the Ultimate Heat Sink. The Ultimate Heat Sink is defined as the source of cooling which at a minimum is capable of providing sufficient cooling to permit safe shut-down of the facility and to meet the minimum cooling requirements for the facility, in the event of any design basis accident (DBA). This safety guide outlined the minimum requirements acceptable by the AEC for any system used as the ultimate sink. The importance of this guideline to the planners of the RHRSW system is evident from recognition of the fact that the heart of their system, the spray pond concept, is considered the ultimate sink for the Susquehanna reactors.

Prior to the release of this guide, Safety Guide 27,(see Appendix), the nuclear industry had no specific guidelines for what the AEC would consider an acceptable "sink" design. Although there has developed over the years a comprehensive set of design criteria covering nearly every facet of a nuclear power plant, this particular aspect, the ultimate sink, was left uncovered. Without these guidelines in the "General Design Criteria for Nuclear Power Plants", as the overall criteria is called, designers were faced with the problem of trying to anticipate the AEC requirements for each separate job. In addition, the requirements set down by the AEC for its applicants were not always consistent.

It was primarily because of these concerns that the nuclear industry requested some specific guidelines from the AEC to clarify their position on this particular matter in the future. The AEC's response was to issue a draft criteria on April 28, 1971, and circulate it throughout the nuclear power industry to those familiar with the problem for their comments and opinions. The main provisions of this draft are as follows:

4.2 Recommended Minimum Requirements for an Ultimate Heat Sink

(1) "The source of cooling water shall be capable of providing sufficient cooling water to permit safe shutdown of the facility (including all units at multiunit sites) and to meet the minimum cooling requirements of the facility in the event of any design basis accident at one of the units.

(2) A single natural source of cooling water shall be acceptable if it is capable of withstanding all applicable conditions including those that could result from earthquakes,

tornadoes, hurricanes, floods, droughts, other severe natural events, and accidents involving water-borne traffic without impairing its capability to the extent that it could not serve as the ultimate heat sink for the shutdown facility for a period of at least 30 days without replenishment of water.

(3) A single source of cooling water, man-made in whole or in part, shall be acceptable if it is capable of withstanding (a) all applicable conditions including those which could result from earthquakes, tornadoes, hurricanes, floods, droughts, other severe natural events, and accidents involving water-borne traffic, and (b) any single failure from unspecified causes of any associated man-made structure projecting above ground level such as a dam or dike, without impairing its capability to the extent that it could not serve as the ultimate heat sink for a period of 30 days without replenishment of water.

(4) In the event that a single source of cooling water with a capability in accordance with (2) or (3) above cannot be provided, then two independent sources, either natural or man-made in whole or in part, shall be required. Each source shall be capable of supplying 100% of the cooling water needs, and the two sources shall be so designed and constructed or be of such a nature that either one of the sources will be capable of serving as the ultimate heat sink for the shutdown facility for a period of at least 30 days without replenishment of water in the event of a single occurrence to the other source of any of the conditions specified in (2) and (3) above.

(5) If a source of cooling water is connected to the intake of the facility cooling water system by a man-made canal or conduit, a single such conduit or canal shall be acceptable if it is capable of withstanding (i) all applicable conditions including those resulting from earthquakes, tornadoes, hurricanes, floods, droughts, and accidents involving water-borne traffic, and (ii) any single failure from unspecified causes of any associated man-made structures projecting above ground level, such as a dam or a dike, without impairing its capability to the extent that it could not serve as the ultimate heat sink for the shutdown facility for a period of at least 30 days without replenishment of water.

(6) In the event that a single connecting canal or conduit from the source of emergency water to the inlet point of the emergency cooling system, meeting the requisites specified in (5) above, cannot be provided, then two independent canals or conduits shall be provided. The two canals or conduits shall be so designed and constructed or be of such a nature that one of them will be available in the event of a single occurrence of any of the conditions specified in (5) above."

Potentially interested parties, such as Bechtel, received copies of this initial draft and had a period of time, 90 days to 6 months, in which to comment. After this time period, the AEC pools all the accumulated information and incorporates the comments they feel important into a workable safety guide, -- in this case Safety Guide 27.

The premiminary draft criteria was issued in late April 1971, a time when Bechtel was well into the process of making a final recommendation for the most promising of the proposed alternate RHRSW systems. Bechtel, however, had received advanced warning from the AEC that a safety guide was in the works and that it would apply to the final design of the "sink" chosen for the Susquehanna power station. This required that the project team working on the RHRSW system had to maintain close communication with the AEC in Washington, D. C., to insure that their designs would meet the forthcoming guidelines. The final version of AEC Safety Guide 27 - Ultimate Heat Sink was issued on 23 March 1972, well after completion of most of the work leading to the final selection of the RHRSW system including the spray pond concept as the Ultimate Heat Sink.

It can be observed by reading Safety Guide 27 (see Appendix), that the AEC does not set specific parameters nor does it set mandatory standards. It is, as its name implies, merely a guideline giving the minimum acceptable requirements for the performance of the system. As long as these requirements can be met, the AEC is not likely to intercede and specify which approach must be taken.

4.3 Amendments 5 and 8 to PSAR

When Bechtel submitted the Preliminary Safety Analysis (PSAR) on 1 April 1971, the AEC's Reactor Licensing Division started immediately to evaluate its contents. At the time it was submitted, the proposed ultimate heat sink was a system using water directly from the river. By this time it was already evident that alternate methods might ultimately prove to be cheaper and more reliable than the river scheme. Since the other alternatives would require additional time to study and develop, it was decided to stay with the base scheme, using the river, to expedite the submission of the PSAR. That section of the PSAR containing the Ultimate Heat Sink could be revised by submitting an amendment after more was known about the alternates. The AEC was then informed of the pending change and asked not to scrutinize that section too closely until it was finalized. The completion of the alternate RHRSW systems study revealed the distinct advantages of subalternate IVa, the spray pond without makeup. After being informed of the outcome of the study, Pennsylvania Power and Light Company agreed with Bechtel's recommendation to amend the PSAR and replace the system using the river with the system described in alternate IVa. On 15 November 1971, amendment number 5 to the PSAR was submitted to the AEC. In addition to giving formal answers to specific questions raised by the AEC, it changed

the Ultimate Heat Sink to the spray pond concept. See Exhibits 4-1 and 4-2, pages 43 and 44 for examples of the types of questions raised by the AEC requiring formal answers. Question 12.3 came from amendment 5, and question 5 was answered in amendment 8 submitted 4 May 1972. These were the amendments made to the PSAR which were pertinent to the RHRSW system.

4.4 AEC Safety Evaluation

When the AEC was satisfied that all of the detailed questions raised about the different systems had been thoroughly answered, they produced their evaluation of the proposed facility. On 17 March 1972, the Commission published a formal safety evaluation of the Susquehanna project in a 160 page report covering every aspect of the proposed facility that could affect public safety or health.

The safety evaluation as it pertains to the ESW and the RHRSW systems is excerpted from the report, dated 17 March 1972 and revised in February 1973 as follows:

"Emergency Service Water and Residual Heat Removal Service Water System"

"The Emergency Service Water (ESW) System is designed to provide cooling water to be used during loss of off-site power conditions or a loss-of-coolant accident. The Residual Heat Removal Service Water (RHRSW) System is designed to provide cooling water for normal cooldown of the reactors, for post accident heat removal, and, if needed, for post-accident flooding of the core or primary containment.

The source of water for both systems will be a pond constructed in the northwest portion of the site. This pond is described in Amendments 5 and 8 to the PSAR. The pond will have a total surface area of approximately 7 acres, an active spray area of about 2 acres, and will contain about 15 million gallons of water. This volume of water is to be large enough so that makeup to the pond is not required to meet cooling requirements of the Station in the event of a Design Basis Accident (DBA) in one unit and a requirement to achieve a safe shutdown of the other unit for a period of thirty days. We find this design criterion to be acceptable.

Evaporative cooling of the pond is provided by pumping the water returned from the ESW and RHRSW systems through a series of spray headers. The applicant has been asked to provide an analysis of the performance of the spray pond and spray system during adverse weather conditions such as startup after a prolonged period of hot or cold weather, and operation during extended periods of limiting meteorological data. These data will be utilized to determine the limiting meteorological conditions at the site and thus is an important input to assure that the final design of the spray pond and spray system satisfie the design criteria. When the design

SSES

QUESTION 12.3:

Provide drawings and a description of the intake structures used to supply water to the RHRSW and ESWS. These drawings and descriptions should show how water for RHRSWS and ESWS flow into the intake pipe under both design high level and design low level river conditions. The effect of river width, depth, and bottom contours on the design and operation of the intake structures should be discussed. Operational considerations should include the proper functioning of the bar racks and traveling screens and avoidance of sedimentation problems at all water levels between design high and low river levels.

ANSWER:

The Engineered Safeguards Service Water Systems' design has been modified to utilize a spray pond for a source of cooling water and as a heat sink. As such, this question on intake structures in relation to RHRSWS and ESWS is no longer applicable.

QUESTION 5:

We require the additional information regarding the spray pond outlined below. Most of this information has been previously discussed with members of your staff.

a. Confirmation that the spray pond will be constructed entirely by excavation; that is, no water retaining dikes or dams will be used. Provide a topographical map having a suitable scale to illustrate how the spray pond will be incorporated into the existing site contours.

b. Confirmation that the spray pond slopes and the spray system itself will be designed for ground motion accelerations of 0.08 g for the safe shutdown earthquake. A conservative dynamic stability analysis should be performed and should consider the most adverse water height conditions in the spray pond, including a complete analysis of the liquefaction potential, and provide a minimum factor of safety of 1.2 for the safe shutdown earthquake condition.

c. Confirmation that the ESW and RHRSW pump house will be founded on bedrock.

d. Provide the minimum and maximum anticipated spray pond operating levels, and discuss the procedures to assure that the minimum pond level is maintained at all times. Provide the pertinent spray pond service water pump house structural elevations referenced to mean sea level (see Fig. Q 12.2.1 of Amendment 5). Also provide section CC of this drawing.

e. Analytically demonstrate that the emergency pond and service water pump house can withstand a local probable maximum flood without a loss of safety related functions. Show that local drainage will be adequate to divert adjacent area runoff around the pond.

f. Provide the minimum pump submergence elevations.

g. Discuss how the spray pond effectiveness will be assured for both winter and summer startup operations. In the winter, for instance, emergency cooling effectiveness would not be available if the spray system and/or pond were frozen. Conversely, start-up during periods of high summer temperatures could be coincident with high ambient pond temperatures.

EXHIBIT 4-2

of the spray pond and spray system is completed, the applicant will provide the requested analyses of the Regulatory Staff for reviewing prior to initiation of construction on these items. We intend to review the adequacy of the final design and supporting analyses to assure conformance with the design criteria."

"Both the ESW and RHRSW systems and their related structures, including the pump house and pumps, are of Class I seismic design. The pump house is designed with a missile wall and concrete dividing wall between the equipment in the redundant loops. The systems are designed so that required cooling capacity is available even in the event of a single active or passive failure in each system. We find the design criteria for these systems acceptable.

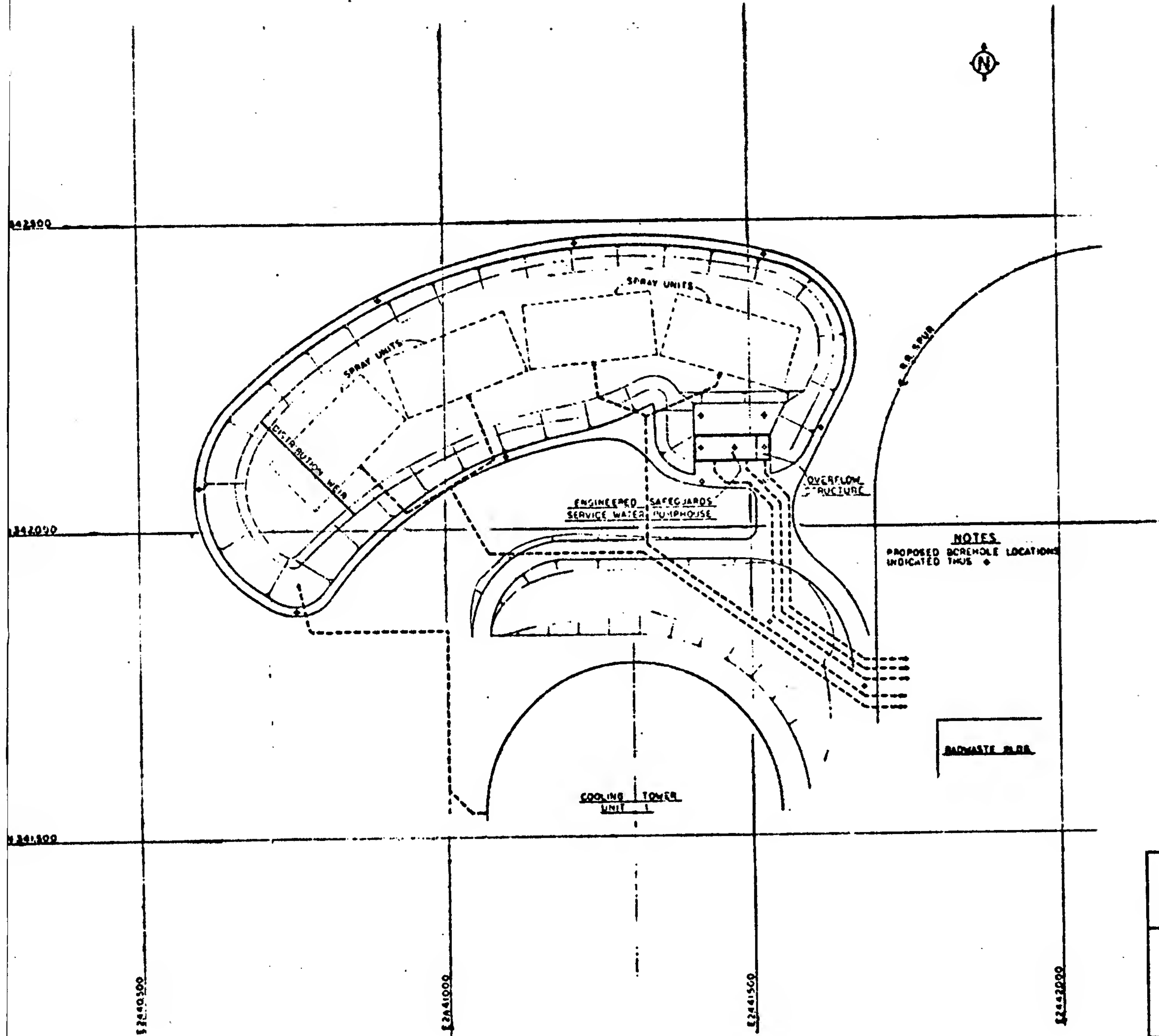
Water from the ESW and RHRSW systems are combined and returned to the spray pond in two common lines. Each of these systems has multiple pumps and the ESW system provides cooling to a number of components arranged hydraulically in parallel. Therefore, achieving an acceptable flow distribution may require considerable effort. We will require that pre-operational testing be performed under a variety of conditions involving inoperative pumps and/or isolated components. This testing will be performed to assure that adequate cooling water is provided to each component under all combinations that may be encountered under normal cool-down and accident conditions."

This review and evaluation of the Susquehanna project at the construction permit stage is only the first step of the continuing review of the design, construction and operation of the plant. When PP & L receives its construction permits, the AEC will review the final design prior to the issuance that all the Commission's safety requirements are met. The plant would then be able to operate only in accordance with the terms set forth in the operating licenses and the Commission's regulations and under continued surveillance of the Commission's regulatory staff.

5. PROGRESS ON THE RHRSW SYSTEM

5.1 Orientation of the Spray Pond

Currently, much of the design work to be done on the residual heat removal service waste system cannot be finalized until a complete meteorological study of the site is finished. The proposed shape of the pond and orientation of the spray units can be seen in Fig. 5-1, page 46. This proposal has evolved by optimizing the required excavation, minimum pipe lengths, and site arrangement. This shape is also advantageous in that its efficiency will remain nearly constant for a wide range of prevailing wind vectors. This is possible because the spray units are positioned in an arc of approximately 60° instead of in a straight line. The efficiency of the spray pond is a function of the prevailing wind vector. This particular design was selected only after Bechtel received a written commitment



PENNSYLVANIA POWER & LIGHT COMPANY
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 AND 2
APPLICANT'S ENVIRONMENTAL REPORT

Layout Of Spray/Retention Pond And Pump Structure

Figure 5-1

from an expert meteorologist that it was his opinion that this was as good a location as any for the spray pond. He based his opinion on meteorological data that had been gathered to date on the site. To confirm the proposed orientation and location of the spray pond, PP&L has contracted the firm of Dames and Moore to gather meteorological data on the plant site for a period of one year.

A good deal of meteorological data is required to determine an accurate statistical weather survey at the site, much more than will be provided by the one year study. To accomplish this, a regression study will be made to correlate the site data with more than 40 years of weather records kept at a small airport (Avoca) located about twenty miles north near Wilkes Barre.

5.2 The Second Pond

A new item which is a potential addition to the system is the second pond. PP&L had requested a second pond be considered for the system for water treatment. This additional 15 million gallon pond would be mainly for such environmental considerations as reducing high concentrations of dissolved solids discharged into the river. It would also keep the year round temperature of pond overflow, discharged to the river, below the 87°F limit imposed by the Pennsylvania State Water Quality Board. However, it was felt that it may be possible to avoid the expenditure of the additional $7,500,000 required to add the second pond. Currently the second pond is being considered as a potential cost trend item. The high potential cost of this addition is not a major stumbling block to the power company because their major concern is to resolve the issue with the licensing body.

6. PROPOSED DEVELOPMENT

6.1 Spray Pond Development Program

The spray pond system will have to be completed and working before the first reactor loads fuel, which is projected to occur in 1979. In order to be ready at that time, there is a rough development program that will be followed. The program consists of five major phases as follows:

(1) Develop a mathematical model to describe the spray pond function
(2) Make small scale tests of different nozzle configurations to determine the best nozzle for the job. (Most critical because evaporation is a function of nozzle characteristics.)
(3) Roughly design a complete system (concurrent with (1) & (2) above)

(4) Make a small scale test model of the spray pond. This model will be field tested in the same location and orientation as that proposed for the final spray pond.
(5) Finish design of the system
(6) Begin construction which would be completed by late 1978.

6.2 Construction Permit

The construction permit which will allow the actual plant construction to begin on the site is scheduled to be issued in October, 1973. All the necessary steps leading up to the construction permit have been taken. The Advisory Committee for Reactor Safety (ACRS) has deemed the basic design to be safe. The Atomic Safety Licensing Board has held public hearings for the surrounding communities discussing safety in January, 1973, and environmental concerns scheduled for July, 1973. All of this information has been supplied to the AEC and they in turn will issue the construction permit. Upon receipt of the permit, construction is scheduled to proceed on the Susquehanna project.

APPENDIX

SAFETY GUIDE 27

ULTIMATE HEAT SINK

A. Introduction

General Design Criterion 44 of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that suitable redundancy in features be provided for the cooling water system to assure that its safety function can be accomplished. This guide describes a basis which may be used to implement General Design Criterion 44 with regard to a particular feature of the cooling water system; namely, the ultimate heat sink.

B. Discussion

The ultimate heat sink (hereinafter "sink") for the cooling water system is that complex of water sources, including necessary retaining structures (e.g., a pond with its dam, or a river with its dam), and the canals or conduits connecting the sources with, but not including, the cooling water system intake structures for a nuclear power unit. If cooling towers or portions thereof are required to accomplish the sink safety functions, they should satisfy the same requirements as the sink. The sink performs two principal safety functions: (1) dissipation of residual heat after reactor shutdown, and (2) dissipation of residual heat after an accident. For a single nuclear power unit, the sink should be capable of providing sufficient cooling water to permit accomplishing each of these safety functions. In considering a multiple unit station, it is recognized that the design of each nuclear reactor unit includes sufficient safety-in-depth that it is highly unlikely that more than one reactor unit will be in an accident condition at any particular time. On this basis, a sink serving multiple units should be capable of providing sufficient cooling water to permit simultaneous safe shutdown and cooldown of all units it serves, and maintain them in a safe shutdown condition, and in event of an accident in one unit, to dissipate the heat for that accident safely and to permit the concurrent safe shutdown and cooldown of the remaining units and maintain them in a safe shutdown condition. The capacity of the sink should be sufficient to provide this cooling for that period of time needed to evaluate the situation, to take corrective action to mitigate the consequences of an accident, and to take any necessary measures to permit water replenishment, if required.

A period of 30 days is considered to be adequate for these purposes. In addition, procedures should be available for assuring the continued capability of the sink beyond 30 days. A lesser capacity than 30 days may be acceptable if it can be demonstrated that replenishment can be effected to assure the continuous capability of the sink to perform its safety functions, taking into account the availability of replenishment equipment and limitations which may be imposed on "freedom of movement" following an accident.

The sink safety functions may be provided by natural or man-made features. More than one water source may be involved in performing these functions under different conditions. Because of the importance of the sink to safety, these functions should be assured during and following the most severe natural phenomena (e.g., the safe shutdown earthquake, tornado, hurricane, flood, or drought). In addition, the sink safety functions should be assured during other applicable site related events that may be caused by natural phenomena such as river blockage, river diversion, or reservoir depletion, or if applicable, other accidents such as transportation accidents involving ship collisions, airplane crashes, or oil spills and fires. Reasonable combinations of less severe natural and accidental phenomena or conditions should also be considered to the extent needed for a consistent level of conservatism; for example, such combinations should be evaluated in cases in which the probability of their existing at the same time and having significant consequences is comparable to that associated with the most severe phenomena.

There must be a high level of assurance that the water sources of the sink will be available when needed. For natural sources, history indicates that river blockage or diversion may be possible, as are changes in ocean or lake levels as a result of severe natural events. For man-made portions, particularly those structures above ground, failures are not uncommon. Because of the condiderations, the sink may need to include at least two water sources, each capable of performing the sink safety functions, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source. Where the sink includes more than one source of water, the individual water sources may have different design requirements. For those individual cases in which an applicant believes a single water source may be acceptable, it must be demonstrated that the source can withstand, without loss of the sink safety functions, the following design requirements:

1. The most severe phenomena expected taken individually;

2. The site related events (e.g., transportation accident, river diversion) which historically have occurred or which may occur during the plant lifetime; and

3. A single failure of man-made structural features. In applying this "single failure",various mechanistic failure modes should be postulated; one may choose to assume a complete functional loss, but this is not necessarily required. For example, the consequences of a postulated major rupture of a dam (including the time-related effects of forces imposed at the time of rupture) should be assumed -- it is not necessarily required that one assume the dam disintegrates instantaneously with total loss of function. As another example, the consequences of a postulated slide of earthen canal walls should be assumed -- it is not necessarily required that one assume water flow ceases completely.

Where canals or conduits are required as part of the sink, at least two should be provided, even if only one source of water has been demonstrated to be adequate. An exception to this requirement is that a single canal may be acceptable if it satisfies the three items above. Multiple water sources, including their associated retaining structures and required canals and conduits, should be separated and protected such that failure of any one will not induce failure in any other that would preclude accomplishing the safety functions of the sink. The complex (but not its individual features) must be capable of withstanding each of the most severe natural phenomena expected, other site related events, reasonable combinations of natural phenomena and/or site related events, and a single failure of man-made structural features without loss of capability of the sink to accomplish its safety functions. In considering the most severe phenomena, they may be considered to occur independently and not simultaneously. In addition, the single failure of man-made structural features need not be considered to occur simultaneously with severe natural phenomena or site related events.

For example, it would be acceptable if Water Source #1 (say a man-made pond with a dam) and connecting conduit were capable of withstanding the safe shutdown earthquake, tornado, and drought, and Water Source #2 (say a river with an existing dam) and its connecting conduit were capable of withstanding the probable maximum flood. However, the complex as a whole must be capable of withstanding any reasonable probable combination of natural or accidental phenomena without loss of the sink functions.

All features of the sink should be shown to be highly reliable. For example, consider Water Source #2, above -- if study indicates that it is reasonable to assume that the river cannot be diverted or blocked sufficiently to affect the availability of water at the connecting conduits, no serious transportation accidents have occurred or can be reasonably expected, and the dam was designed to appropriately conservative requirements, has functioned properly over its lifetime, and based on

projections of the best available data, will function properly for the lifetime of the nuclear power units it serves, then such a showing would be sufficient to establish that this source is highly reliable. It would not, however, remove the need for another source of cooling water, if a single failure of the dam could result in losing the cooling capability of this source of water. Newly constructed features not required to be designed to withstand the safe shutdown earthquake or the probable maximum flood should at least be designed and constructed to withstand the effects of the maximum earthquake determined on the basis of historic seismicity at the sink site and water flow based on historical events in the region.

The importance of the sink to safety requires that if during operation its capability is threatened or degraded below a specified safety level, as for example, to permit necessary maintenance or as a result of a casualty, restrictions should be placed on plant operation. The technical specifications should state the actions to be taken in the event the required capability of the sink is temporarily unavailable during plant operation. For example, the technical specification may require that: (1) the Commission be notified if the sink does not satisfy the specified safety level, and (2) if its capability cannot be restored to this safety level within a reasonable period of time, all units served by the sink be shut down and remain shut down until this capability is restored.

C. Regulatory Position

1. The ultimate heat sink* should be capable of providing sufficient cooling for at least 30 days (a) to permit simultaneous safe shutdown and cooldown of all nuclear reactor units which it serves, and maintain them in a safe shutdown condition, and (b) in the event of an accident in one unit, to permit control of that accident safely and permit simultaneous safe shutdown and cooldown of the remaining units and maintain them in a safe shutdown condition. Procedures for assuring a continued capability after 30 days should be available.

*The ultimate heat sink is that complex of water sources, including associated retaining structures, and any canals or conduits connecting the sources with, but not including, the intake structures of nuclear reactor units. If cooling towers or portions thereof are required to accomplish the sink safety functions, they should satisfy the same design requirements as the sink.

2. The ultimate heat sink should be capable of withstanding the effects of the most severe natural phenomena associated with its location, other applicable site related events, reasonably probable combinations of less severe phenomena or events where this is appropriate to provide a consistent level of conservatism, and a single failure of man-made structural features without loss of the capability specified in regulatory position 1. above.

3. The ultimate heat sink should consist of at least two sources of water, including their retaining structures, each with the capability to perform the safety functions specified in regulatory position 1. above unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source. There should be at least two canals or conduits connecting the source(s) with the intake structures of the nuclear power units, unless it can be demonstrated that there is an extremely low probability that a single canal can fail entirely from natural phenomena. All water sources and their associated canals or conduits should be highly reliable and should be separated and protected such that failure of any one will not induce failure of any other.

4. The technical specifications for the plant should include actions to be taken in the event that conditions threaten partial loss of the capability of the ultimate heat sink or it temporarily does not satisfy regulatory positions 1. and 3. above during operation.